THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 2 OCTOBER 1938 NUMBER 4

CENSUSING QUAIL IN EARLY FALL[1]

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and
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In 1916 Iowa closed the bobwhite[2] shooting season and gave the bird legal protection from hunters by legislative enactment. At that time it was realized that the quail population in the State was very low in proportion to what it had been from 1875 to 1900. Overshooting was assumed to be the main cause for the population decline between 1900 and 1916. From 1916 to 1930 the quail was almost a forgotten bird from the hunting standpoint, although it remained on the game-bird list. With the formation of the Iowa Fish and Game Commission in 1931 and the publication of Aldo Leopold's (1931) game survey, interest was aroused in the management of the species with the objectives of bettering the quail environment in Iowa and perhaps of taking the yearly surplus as game.

An intensive educational campaign was carried on in southern Iowa, 1932 to 1935, to acquaint nature lovers, sportsmen, and farmers with the plans of the Fish and Game Commission and with ways of producing sustained yields of quail. The writers took active parts in this program, one with the Fish and Game Commission and the other with the Extension Division of Iowa State College. The educational phase continues to be a vital part of the cooperative wildlife program in the State.

In more recent years it has been the consensus of opinion that intensive agriculture had eliminated many essentials of quail environment, particularly winter cover. Leopold's survey and the subsequent findings of others showed, however, that there was much stable quail environment in a number of the southern counties. In fact, there appeared to be a yearly surplus of bobwhites in many of the more rolling counties. Errington and Hamerstrom (1936) reported on a large number of covey ranges and determined that a given covey range had a carrying capacity of a certain maximum number of quail so long as the environment remained substantially the same and that the birds above that number in each unit were doomed. It was the birds above the carrying-capacity population that could be used for game without injuring the permanent population.

In 1933, by legislative enactment, the Iowa Fish and Game Commission allowed the hunting of quail on 14 experi-

[1] Journal Paper No. *J542* of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 494. Iowa State College, Iowa Conservation Commission, and American Wildlife Institute, cooperating with the United States Bureau of Biological Survey.

[2] *Colinus v. virginianus.*

mental areas, totaling 24,252 acres, in southern Iowa. The next year it was found that controlled shooting in 1933 on experimental areas did not prevent recovery of the quail population. During 1934, 257,833 acres in 104 game-management areas in southern counties were opened to quail hunting.

In 1935 the Iowa Fish and Game Commission and the Iowa Conservation Board were united into the present Iowa Conservation Commission. By that time several hundred game-management areas had been established and those in southern and eastern Iowa opened to the controlled hunting of quail. Relatively few quail were taken during the period 1933 to 1935, for most of the hunters were inexperienced and trained bird dogs were scarce.

The winter of 1935–36 proved to be the most severe ever recorded for the State. Green and Beed (1936), in an investigation of the effect of that winter on Iowa quail and pheasants, showed that a substantial seedstock had survived in the southern counties. The following spring and summer brought floods, summer drought, and hordes of devastating grasshoppers to quail ranges in the western half of southern Iowa. The quail reproduction during the summer remained unknown through August. The Conservation Commission had the authority to close the season if that were found necessary. As a guide to action, the Commission was obliged to learn what the quail situation was after such abnormal weather and biotic conditions.

During late August and early September the writers attempted to work out a census method that would enable the commission to obtain population data in time to take action on the proposed hunting season. The daily temperature during the late summer months often approached 100° F., and by August and September the vegetation, to a great extent, was burned by drought and eaten by grasshoppers. The writers covered quail ranges on foot at all hours of the day attempting to check quail populations. The ranges were covered systematically, but the results were scant, and at the rate the birds were being found, that method clearly would not produce data quickly enough for use in determining the status of the quail population before the usual shooting dates.

Bird dogs had not been used because the almost universal opinion of experts was that the abundance of pollen from numerous plants, together with high temperatures, renders a dog almost useless for bird scenting during August and September. Nevertheless, an experiment was made, and to mitigate the unfavorable factors named, the hours selected were from 6:00 a.m. to 8:00 a.m., when the vegetation was usually dripping with dew, and the pollen, therefore, mostly bound. The temperature in early September at those hours was usually between 50° and 60° F., and it was found that the bird dog could work efficiently. About 8:00 a.m. the temperature began to rise rapidly and the dog became useless. Using a well-trained pointer dog, the writers revisited areas previously covered without a dog and found birds rather readily. The dog located quail in ten out of twelve covey ranges. The results indicated that a satisfactory census could be made.

This preliminary information led

Fred Schwob, Chief of Game and Fish, Iowa Conservation Commission, in 1936, to try the method on a larger scale. Five conservation officers who had bird dogs and could handle them were chosen to make the census. Each officer was instructed to survey three typical quail ranges in the southern, central, and northern parts, respectively, of each county. Each man had three counties to census, and each spent nine days at the task during the period September 18 to 28. One hundred and twenty-eight ranges were satisfactorily checked, and 1,290 quail were reported. The finding of quail in about 80% of the covey ranges at that time of year assured the Commission that the quail season could be opened safely, and it was opened in 20 counties. Reports by hunters and conservation officers and observations by the writers during the hunting season and the winter confirmed the findings of the September census.

The winter of 1936–37 was nearly normal and no great losses of quail were reported. Abundant rainfall the following spring and summer caused a luxuriant growth of all vegetation, hence the census was delayed until October. The same conservation officers were chosen to make the census in 1937 as in 1936, and the same counties were selected. The census was made October 11 to 22, and 103 typical covey ranges were checked and 1,350 quail reported. On these 103 covey ranges, quail were found on 93. Observations made during the fall and early winter sustained the census and confirmed the indication of a greater population than in the previous year in the counties open to shooting.

The writers do not claim that this kind of census is perfect, but from the standpoint of the Conservation Commission it has several good points. It is fairly accurate, and it is inexpensive, as only ten to twelve days are required for its completion, and only two hours a day are taken from the conservation officers' time. The results can be used as a basis for the opening or closing of the season in time for the dissemination of newspaper releases and official notices. Furthermore, the method can be quickly learned by any sportsman who has a well-trained dog and who is acquainted with quail and their habits.

LITERATURE CITED

ERRINGTON, PAUL L., and F. N. HAMERSTROM, JR.
1936. The Northern Bob-white's Winter Territory. Agricultural Experiment Station, Ames, Iowa. Bulletin 201.

GREEN, WILLIAM E., and WATSON E. BEED,
1936. Iowa Quail and Phesants in Winter. American Wildlife, November-December.

LEOPOLD, ALDO
1931. Game Survey of the North Central States. American Game Association, Washington, D. C.

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PROTECTION OF MOUNTAIN APIARIES FROM BEARS BY USE OF ELECTRIC FENCE[1]

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Nature often has woven a strange fabric of interrelations between various species of animals and plants in the wild, and nowadays some equally complex situations are arising in the field of economic zoology where the activities of different species of animals touch diverse human interests. Thus, the evolution of agricultural crop production in the lowlands of California has now affected the wild black bears in the Sierra Nevada, and the aid of an electrical engineer was necessary in the chain of adjustments that had to be made!

Early crop production in the great central (Sacramento-San Joaquin) Valley of California was chiefly of cereals, as depicted in Frank Norris' novel, "The Pit." In time, the development of the automobile and tractor largely replaced use of horses and mules in transportation and farm operations, and lessened the demand for hay and grain production. Meanwhile, levees and dikes had been built by drainage engineers, confining winter flood waters to proper channels, and a regulated irrigation made fruit and vegetable production more practicable on many rich river bottom lands. Studies in human nutrition had revealed the desirability of greater quantities of fruits and vegetables in the human dietary, and improvements were being made in methods for fresh shipment and for canning these products. In consequence of these and other factors thousands of acres in the Sacramento-San Joaquin Valley are now devoted to commercial production of fruits and vegetables.

Bee keeping has increased in the valley as a means of using floral by-products and also as an aid to cross pollination for fruit trees, but apiarists experience difficulty in maintaining their colonies because the summer forage supply for bees is irregular. The fruit blossoms afford a large supply of pollen and nectar through a brief period in early spring. Annual vegetation provides bee forage until it begins to dry up, ordinarily early in May. Alfalfa and star thistle blossoms are available in late summer.

The presence of thousands of acres of single species of crop plants in turn affords a favorable "culture medium" for insects and other pests, and these also have increased and spread. Efforts to reduce or control such pests now involve use of large quantities of toxic chemicals that are dusted on the plants, Some of these substances, especially compounds containing arsenic, are poisonous also to hive bees. Worker bees visiting the blossoms of dusted plants and other blossoms nearby onto which the poison dust has drifted become contaminated with the poison. This is transported with pollen (but not with nectar[2]) to the hives, where it becomes

[1] Joint contribution from the Divisions of Zoology and Agricultural Engineering, College of Agriculture, University of California, and the Pacific States Bee Culture Field Laboratory, U. S. Department of Agriculture, Davis, California.

[2] Despite repeated tests no evidence has

mixed with the food stores and leads to decline and even decimation of the colonies. Numerous beekeepers in the lowlands have suffered important losses from this source, and queen-rearing has become all but impossible in some places.

Another difficulty confronts apiculturists in the foothills and lower mountains surrounding the central valley in that the California buckeye (*Aesculus californica*), native to the region, produces in its flowers, a substance causing deformity and paralysis in hive bees. Safe use of the foothill region by bee-keepers must, therefore, be limited to times of year other than when the buckeye is in blossom.

As a result of the seasonal limitation in bee forage, the hazard of poison dust, and the buckeye problem, beekeepers in the lowlands have sought other regions for pasturing their bees.

In the mountains of California during the summer season there is a supply of plants that afford nectar, pollen, and honey-dew suitable for hive bees. Use of this bee forage, on a seasonal basis, like the highland pasturing of sheep and cattle, has been made by some few beekeepers for many years, but the practice has been increasing of late because of the difficulties encountered in the lowlands. Perhaps 200 beekeepers, from Tulare County on the south to Shasta County on the north, now follow this practice; a lesser number do so in Oregon and Washington.

Due to the differences in season conditioned by altitutude, from the lowland valleys to the middle heights in the Sierra Nevada, the migrant beekeeper may pasture his bees on the spring and early summer flora of the Great Valley, then move into the mountains and again find a "spring" flora.

Many of the beekeepers in California are specialists, maintaining large numbers of hives; two at least have 3,500 or more colonies, and a considerable number have upwards of a thousand apiece. These cannot be maintained profitably in a single locality but must be scattered. In winter and spring the hives belonging to such large operators are distributed in groups of fifty to one hundred or more in various orchards and other sites in the lowlands. Hives so placed are under more or less constant surveillance on farm properties and are seldom molested.

When the colonies are taken to the mountains, placement at separated sites is also necessary. Since farms are scarce in the mountains, it is impossible to locate many of the apiaries where they will be guarded; many are of necessity in small isolated clearings in the forest.

The middle altitudes of the Sierra Nevada mark the center of abundance of the native black bear, and the interest of bears in honey is proverbial. The difficulties experienced in this region by beekeepers may be readily imagined; many have sustained frequent and serious losses from bears. It is impossible for the beekeepers to erect stockades about their apiaries in the mountains because of the expense for labor and materials that would be involved. Neither is it practicable to establish the hives on stout bear-proof platforms. Need exists for a practical and economical means of protecting aggrega-

been produced to show that the honey in hives is contaminated with the poison.

tions of bees in the mountains from raiding by bears.

During the World War electrified wire stockades were used as a means of holding prisoners. Within recent years this basic idea has been transferred to agricultural use for confining livestock on farms, and, latterly, in a minor way, it has been employed to exclude deer from crop lands. Several types of devices have been developed commercially in the United States for electrifying metal farm fences. Most of these depend upon the availability of power lines carrying alternating current. With these devices the fence voltage may be anything from about 90 volts to 1,000 volts. Some method of limiting the current is incorporated in the secondary circuit in order to reduce the hazard to human beings. Since mountain bee yards are seldom at sites served by power lines, recourse must be had to equipment energized by batteries, and further discussion in this paper will be confined to battery sets.

Equipment for protection by electric fence of a field bee yard includes: (a) Battery as source of energy; (b) Fence controller unit containing: (1) interrupter and coil for producing intermittent shock and (2) current limiting device; (c) Fence posts; (d) Fence wire on insulators fastened to the posts and connected to one side of the controller output; and (e) Chicken wire "threshold" around outside of fence connected to the other, grounded, terminal.

Either dry or storage batteries may be used. Weatherproof units containing four 1.5-volt dry cells (telephone type) should serve continuously for 3 months under field conditions; these cost about $2.00 per set. Storage batteries, such as used for automobiles, have ratings of 90 ampere hours or higher; one should operate a fence unit for 90 days, under proper care, without recharging. (These statements are based on tests made under field conditions in 1937.) Storage batteries are higher in initial cost, heavier to transport, require recharging at intervals, and need replenishment of water to maintain the proper level of the electrolyte. In general, dry-cell units seem more practical.

The controller contains an interrupter that serves to break the d.c. current from the battery, causing a change in the voltage and current relations in the primary windings of the coil and inducing a transient voltage in the secondary; this higher voltage is used to charge the fence wires. The interrupter also performs two important additional services; namely, it permits a person or animal that has come in contact with the fence to break away between shocks and by intermittent use it conserves the battery energy. Field installations have involved use of shock intervals of from 73 to 12 impulses per minute, but the latter is too slow; the most useful range lies within these limits; 30 to 50 impulses per minute are adequate.

The coil serves to "step-up" the 6 volts of the primary (battery) source for application to the fence. Since the current and consequently the hazard to human beings increases as the voltage is raised, means must be used for keeping the output within safe limits, certainly in respect to the current and possibly also as to voltage. Human deaths have occurred with shocks of as low as 50 volts, but general experience suggests that somewhat higher voltages can be used if the current is held to not

over 15/1000 of an ampere (15 milliamperes). The exact limits for safe use are unknown.

The assembling of equipment for electric fence operation by amateurs is emphatically condemned by the writers because of this hazard. For example, an automobile ignition coil with 6-volt primary may produce as much as 15,000 volts potential in the secondary. Personal experience with such outputs, even when the operator is not effectively connected to the grounded side of the circuit, is such as to discourage use of such equipment for energizing a fence. Indeed, *none of the manufactured equipment thus far available in California for electric fences, either for battery or power line operation, meets the approval of the California Industrial Accident Commission!*

It seemed desirable to conduct preliminary experiments on the effect of an electrified fence on bears before establishing such fences about mountain apiaries. Fortunately there exists in central California an area with a disproportionately large black bear population—in Yosemite Valley.[3] Two test fences, each enclosing an area about 24 feet square, were constructed in the lower western part of the Valley where bears are common. One fence consisted of 5 strands of barbed wire, the lowest, middle, and topmost of which were mounted on solid porcelain insulators and connected "in parallel" to one output terminal of a fence controller. The other two wires were stapled directly to the supports and grounded to a rod about 10 inches long driven into the then *wet* soil. The wires were placed at 6, 14, 24, 35, and 48 inches, respectively, above the ground. The second fence was of smooth (unbarbed) wire, similar in construction to the first, save that an additional wire on insulators was placed 54 inches above the ground. Trees were used as the main means of support for the wires. Both fences proved to be of adequate height because the bears neither tried to jump or climb over.

Two types of controllers were used, one with a much stronger ($\frac{3}{8}''$) spark than the other. Both types of equipment were effective save that in one case when using a 4-second interval between shocks, one bear passed through the smooth wire fence. The stronger coil caused a more violent reaction on the part of the bears.

Cured ham and bacon, fresh beef and fish, as well as honey and brown sugar, were exposed in both enclosures for bait, and bacon rind was rubbed on the "hot" wires.

Neither fence was energized during the first night, and the bears then passed freely in and out to secure food.

Then the fence wires were connected to the controllers, and during the succeeding 6 days about 15 bears were observed to come in contact with the wires. In general, all responded alike to the shock—a backward jerk, a quick turn, and a running departure! One bear, after running some distance, climbed a tree and remained there for an hour. This particular individual instead of "taking it" on the nose or lips, as did the others, reared up on its hind legs and placed its forepaws on the top wire. The ground connection, in the

[3] The administrative officials of Yosemite National Park very kindly permitted tests and collaborated generously in the work. We are indeed grateful for their aid.

TABLE 1
ELECTRIC FENCES USED IN CALIFORNIA TO EXCLUDE BEARS, DURING 1937

No.	Location	Length in feet (approx.)	Fence wires, spacing (inches above surface of earth) and connections to controller						Ground conditions just outside of fence	Nature and spacing of supports	Comment and Results
			1	2	3	4	5	6			
1	Yosemite Valley May 3–10	100	6 +	14 −	24 +	35 −	48 +	54 + (smooth wire) —grounded	Damp; 36″ strip raked clean	Trees at about 10 feet	Experimental; of smooth wire; one bear entered (when shock interval was 4 seconds) remained inside until observer returned, then broke out; no others in 8 days. Satisfactory
2	Yosemite Valley May 3–10	100	6 +	14 −	24 +	35 −	48 +	0 (barbed) —grounded	Damp; 36″ strip raked clean	Trees at about 10 feet	Experimental; wire with barbs 5″ apart. No bears entered in 8 days of test. Satisfactory
3	Near Viola, Shasta Co. (J. E. Wing) May–Sept.	700	6 +	16 to 20 −	32 to 36 +	44 to 46 −	0	0 (barbed) —grounded	Dry; 36″ strip raked clean	20 to 30 feet apart	Around apiary; one small bear entered and remained overnight, then shot; measured 24″ high at shoulder. Not Satisfactory
4	Near Viola, Shasta Co. (C. G. Wenner) May–Sept.	200	18 +	0	0	0	0	0 (barbed) —grounded	Dry and clean	Posts	Around apiary; bears visited site before fencing; none for a week, but later entered. Not Satisfactory
5	Near Viola, Shasta Co. (C. G. Wenner) May–Sept.	225	6 +	20 to 25 −	30 to 36 +	0	0	0 (barbed) —grounded	Dry; pine needles not removed	Trees at 20 to 25 feet	Around apiary; one entered, upset hive but ate nothing; spacing between "posts" too great. Not Satisfactory
6	Near Viola, Shasta Co. (J. E. Wing) May–Sept.	2,000	6 +	16 +	28 +	0	0	0 (barbed) —grounded to wire screen	Cleared and 18″ screen wire on ground surrounding fence	Grape stakes 36″ high every 10 feet	Around large apiary; used ground screen. Satisfactory
7	Near Viola, Shasta Co. (J. E. Wing) Aug. 12–Sept. 17	2,500+	6	16	26	36	0	0 —grounded to wire screen	Cleared and 12″ screen wire on ground surrounding fence	Wooden posts	Around large apiary; owner could not keep bees at this site earlier. Satisfactory

cases actually observed, was provided through the feet of the bears rather than through either of the grounded wires.

One entry in the field notes will serve to indicate the general reactions of the bears *after* the fence was once contacted: "May 7, 1937. 1:30 P.M. A medium-sized brown bear came from the woods, circled the pens cautiously twice in 10 minutes, sniffed and looked intently at the bait. It did not approach closer than within about 7 feet of the fence, but went away, eyeing the fence 'suspiciously' as it departed."

Later, trails of brown sugar were made outside leading up to and within the fences. This was necessary because the bears had become "wise" and ceased even to approach the fences until the sugar trails were laid down; the bears that approached (during night time) scratched out the earth under the fence to a depth of 3 to 4 inches and reached inside some 5 to 7 inches in efforts to obtain the sugar. In these

cases it seems probable that the shock was received through the hair on the legs. No tendency to dig was noted before the sugar was placed nor was there any in places without sugar. It is remotely possible that digging might be extensive enough in time to permit passage under the wire.

The bears were not injured or driven from the area, as on the last night 17 bears came to the pits nearby where garbage is regularly fed to them. All of them, however, shunned the electrified fences. The food within the fences was still attractive to them, for as soon as the fences were removed, the bears cleaned it up.

The degree of success attained with the experiments in Yosemite encouraged field trials and during the summer season of 1937 five fences were constructed by beekeepers in the vicinity of Viola, Shasta County, near Lassen Volcanic National Park. Details as to all the fences used and the results obtained are given in Table 1.

Results from the trials in 1937 indicate that a substantial fence (as used for livestock) is needed, supported at short intervals by good posts or trees, and with 3 or 4 barbed wires on insulators all connected to one output lead of the controller. The spacing of the wires must be different than for the usual stock fence. On damp soils the other lead may be grounded to a metal stake driven into the earth, but where the soil surface becomes dry, an artificial "ground" as of poultry netting is required. The time between successive impulses must not be long enough to permit an animal to pass through the fence during the interval.

Experience thus far indicates that protection of apiaries (and probably other establishments) from bears may be had with an electrified fence constructed according to the following specifications:

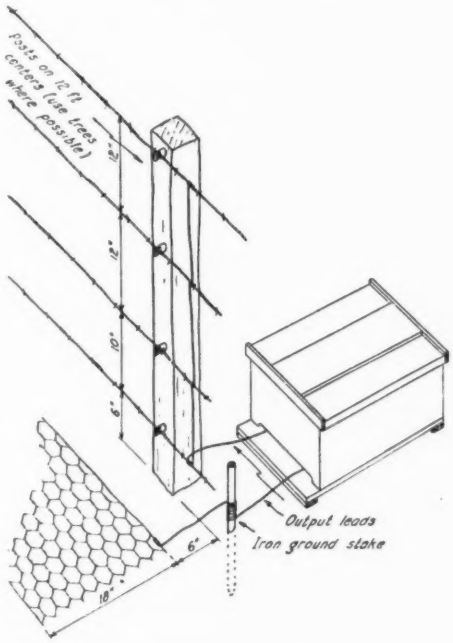

Fig. 1. Design for electrified fence to exclude bears from mountain apiaries. Battery and "controller" housed in empty hive or other weather-proof shelter inside the fenced enclosure. Four (or three) wire fence, "ground" of poultry netting, connected to ground stake and to one side of controller output. Fence wires (on insulators) connected in parallel to other output wire of controller.

1. Substantial wooden posts not more than 12 feet apart (trees may be used as available).

2. Four-strand barbed wire fence, strands 6, 16, 28, and 40 inches above the ground, all connected (in parallel) to the "hot" or "live" or "fence" terminal of controller.

3. Battery operated fence controller with interrupter that breaks current not faster than 50 times per minute, limits duration of shock to not more than 0.1 second and current to not more than .015 ampere.

4. Poultry netting 18 inches wide laid on the cleared ground around outside of fence (about 6″ out from posts) and connected to "ground" terminal of controller and to a metal stake driven 10″ or more into the earth.

5. Four-cell (6-volt) dry battery unit.

6. Weatherproof box to house battery and controller.

Such a fence should be marked conspicuously with signs at frequent intervals to warn people that the wires are charged.

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A. (*Upper*)—Bulldozer blade equipped with steam shovel teeth.
B. (*Lower*)—Machine just digging in.

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A. (*Upper*)—Heaving a root system much larger than would be expected in small brush. It is often necessary to lift these as shown and get another bite before removing them.

B. (*Lower*)—Rocky soil can be worked.

A. (*Upper*)—Scrub oak thickets like this offer little resistance to the bulldozer.
B. (*Lower*)—Land cleared by bulldozer and sown to rye.

USE OF POWER IN MAKING SMALL CLEARINGS IN BEAR OAK BRUSH FOR WILDLIFE

M. C. Howard

In 1936 the staff of the George Washington National Forest was faced with the problem of improving the cover composition on the Big Levels Wildlife Management Area. This 31,000 acre area is largely of low site quality, being composed almost entirely of sites IV, III, II. Site IV, on the upper slopes and ridges which makes up about 60% of the area, is covered with a dense stand of bear oak (*Quercus ilicifolia*) which provides an abundance of food during the fall season, but affords little variety at any time during the year.

Due to the density of this type and the lack of diversified foods this part of the area is little used by turkey, grouse, and deer. The desirable herbaceous growth is smothered out under the dense bear oak stand and with the exception of trail borders the area is of little value.

The problem was one of creating more desirable interspersion throughout this bear oak type. Supporting this growth is a rocky sandstone soil, which precluded the possibility of using a brush-cutter of the type described in Mr. H. L. Stoddard's article in the July issue of the JOURNAL OF WILDLIFE MANAGEMENT.

A 55 H.P. bulldozer or trailbuilder was drafted into service for this job. Two different types of blades were used, the regular smooth trailbuilder blade was used first and found unsatisfactory, as this type of blade would ride out of the ground and bend the larger trees over, forming a brush-like mat which was difficult to remove.

Steam shovel teeth were then welded to the edge of the smooth blade converting the blade into a ripper. (Pl. 9-A) In order to keep brush from clogging in the teeth edge, the face of the blade was built up by welding a road grader blade over the row of teeth. This type of blade proved most satisfactory and in the operation of this blade best results were obtained by allowing the trailbuilder to go over the brush with the blade just touching the ground. This operation pulled 80% of the smaller brush up by the roots. A second time over, the teeth were allowed to dig in about 10 inches, clearing the remaining root systems.

This modified trailbuilder proved exceptionally successful in the work for which it was developed. Rocky soil can be handled satisfactorily and roots are cleared out of the soil more thoroughly than by any other method that has been tried, including hand labor.

After the successful operation of this machine in the bear oak type it was given an experimental run on areas that had been cut for pulling. The stumps on these areas were up to 15 inches in size. The trailbuilder again proved effective and economical and reduced the stump pulling cost 50%.

Tracts ranging from 1 to 14 acres were cleared on the Big Levels Wildlife Management Area, 31,000 acres in extent. An average of approximately one

acre of land was cleared to each 185 acres of the management unit. These plots were spaced throughout the refuge to give a more desirable interspersion of cover types. The clearings are now being sodded and with the little sprout growth that has occurred, are expected to remain in the field type for a long time.

As repeated forest fires had destroyed most of the nesting cover, the brush and small logs removed from these areas were scattered around the clearing borders to improve grouse nesting conditions.

The machine stood up well under a severe test, even handling rocks up to 3 feet in diameter. It will be noted that one tooth is missing in the illustrations and a word of explanation is necessary. This tooth was broken when the machine hit a large stump that had been cut off at ground level. The bulldozer was traveling at a rapid rate when this occurred. When the machine was eased into heavy work, no difficulty was encountered. In the fairly rough going of this job, it was found possible to clear .8 of an acre per six-hour day. The machine was operated at a cost of $1.10 per hour, which includes fuel, lubricants, depreciation, and repairs. Adding the operator's salary, the land was cleared by this machine at the rate of $16.00 per acre. This proved to be about $\frac{1}{10}$ the cost of land clearing with hand labor and $\frac{1}{8}$ the cost with hand labor and tractor pulling of stumps.

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A
B

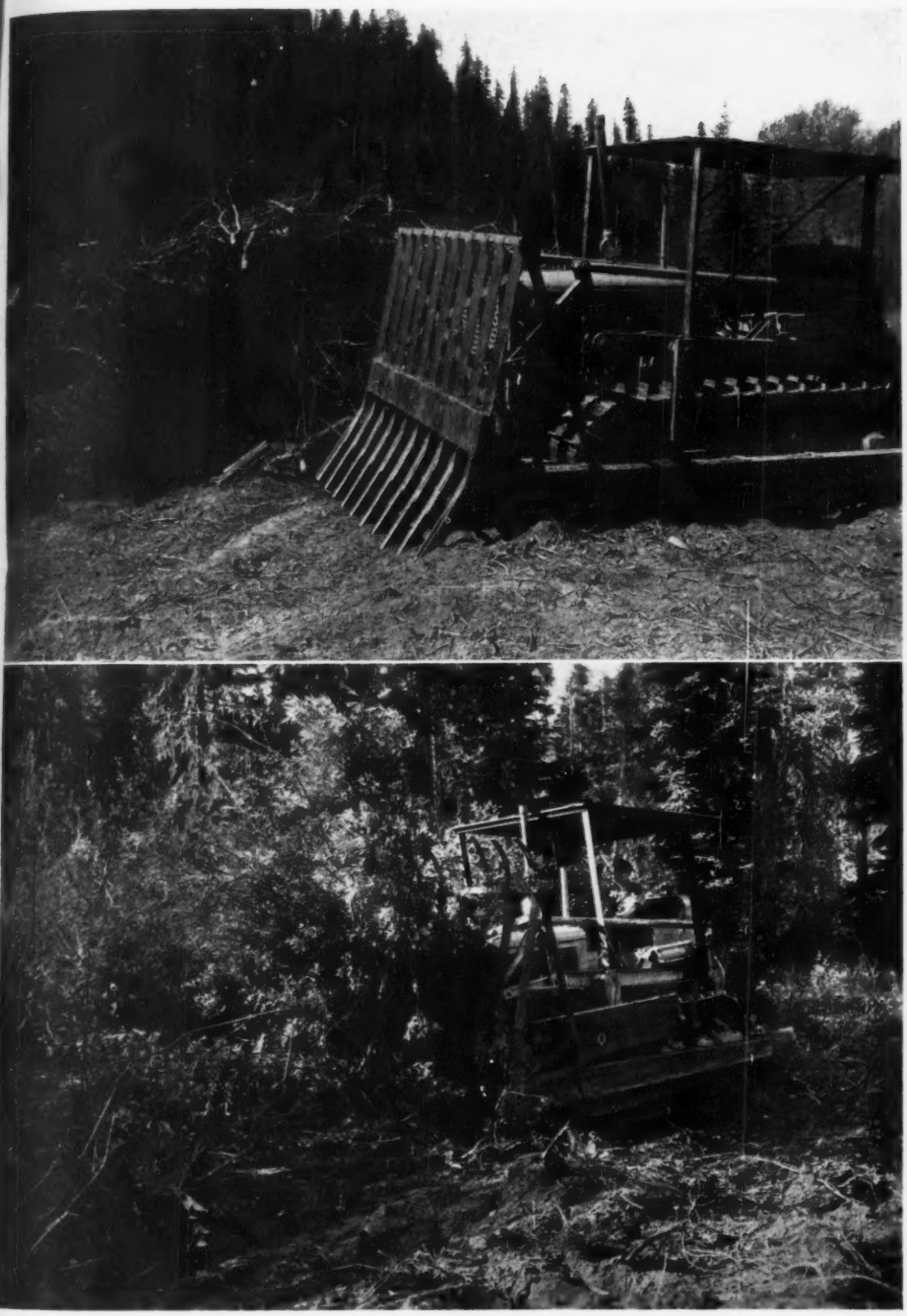

Plate 12

A. (*Upper*)—Bulldozer with special brush rake.
B. (*Lower*)—Bulldozer clearing brush.

Plate 13. Areas cleared with bulldozer showing brush piles to be burned.

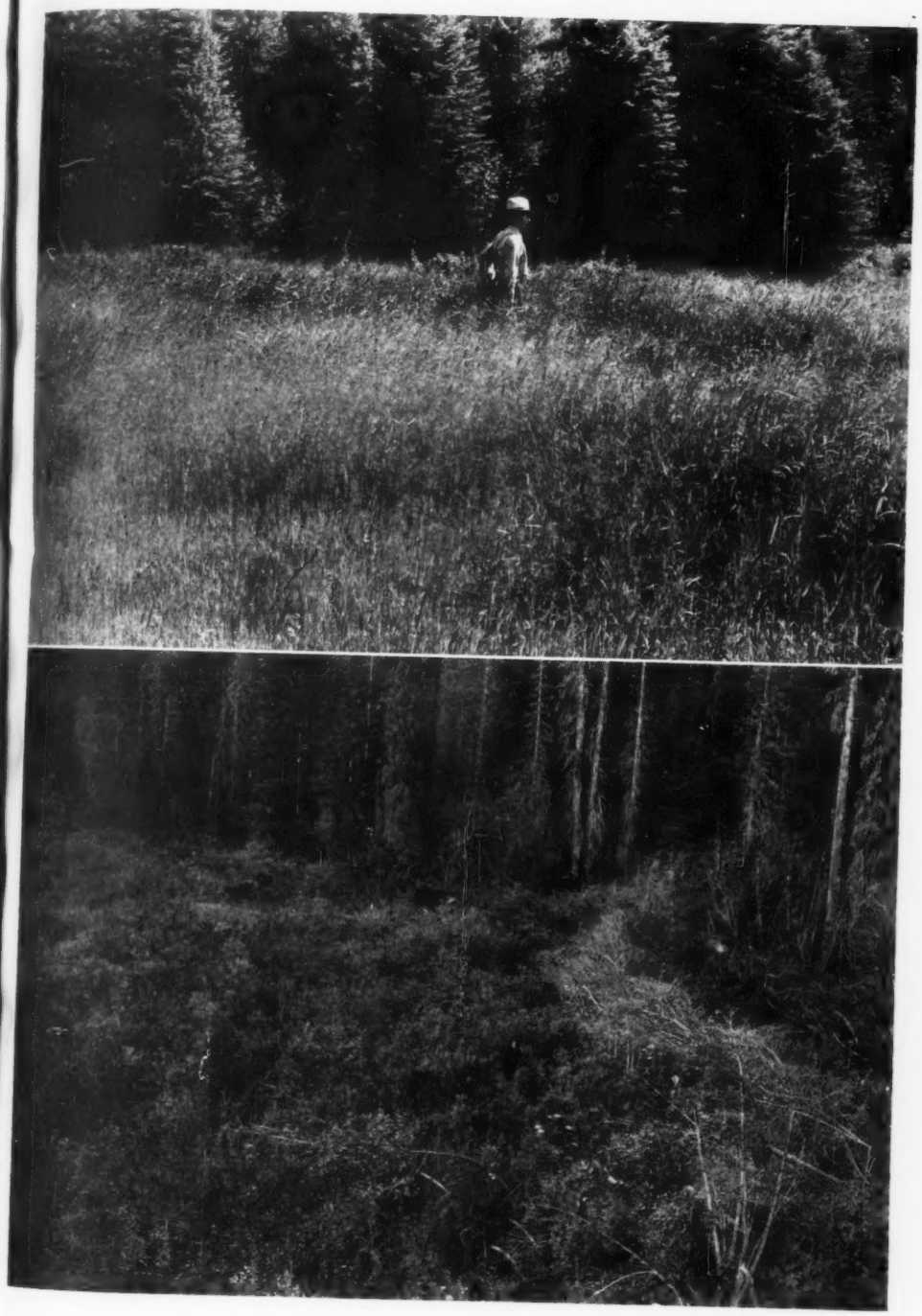

Plate 14

A. (*Upper*)—Grass established on bulldozer area one year after clearing
B. (*Lower*)—Area *x* before clearing.

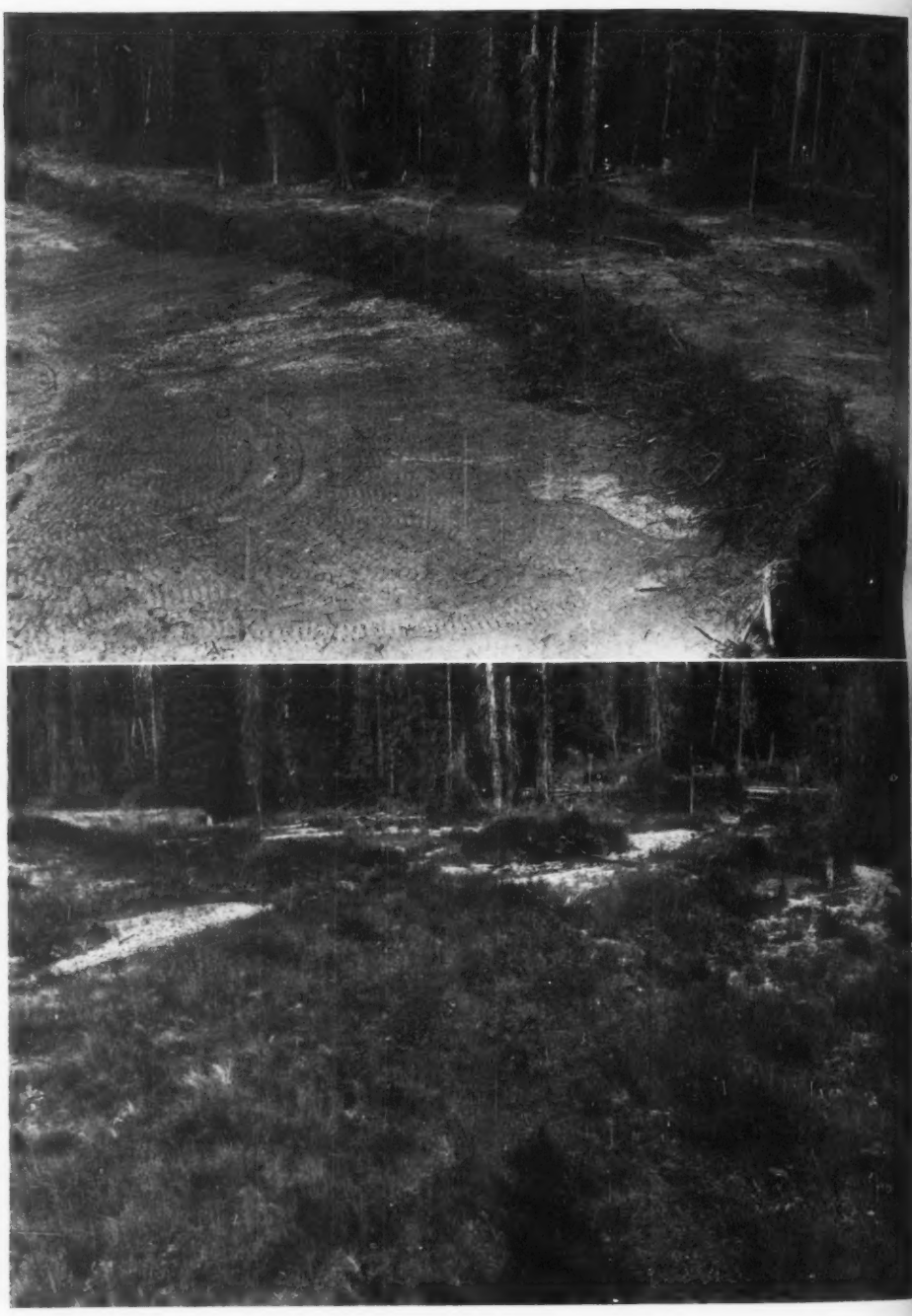

Plate 15

A. (*Upper*)—Area *x* after clearing, showing windrows of brush.
B. (*Lower*)—Area *x* a year later with grasses becoming established.

LAND CLEARING BY POWER METHODS IN THE CONTROL OF WHITE PINE BLISTER RUST

Herman E. Swanson

To eradicate wild currants and gooseberries for the control of white pine blister rust, it has been necessary on some alluvial bottom lands, where these bushes grow in dense concentration tangled with willows and other species, to clear the area completely of all brush by the use of the so-called bulldozer. The bulldozer is a tractor of the caterpillar type and is similar to the machine used in road construction, with the exception that the solid blade used for moving dirt is replaced with a heavily constructed frame holding a series of digging teeth (Plate 12-A). The frame or brush rake was specially designed by the Division of Plant Disease Control of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, for clearing brush and *Ribes* from stream bottoms.

In use the teeth in this special blade are set to penetrate 3–4 inches into the ground, or deep enough to catch the roots. The brush rake can be raised or lowered as the machine moves over the ground. As the bulldozer moves ahead, the brush is collected in front of the rake and is pushed into a pile or windrow. The brush piles are burned in the fall or in the following spring. After the brush is burned, the area is planted to grass. Many of the areas cleared by the bulldozer have been converted into pasture land, while some have been put under regular cultivation.

The average cost of clearing land by this method is $50 per acre. The work is done where the currant and gooseberry plants are so situated in bottom lands that white pine blister rust could spread from them to extensive white pine stands on adjoining hillsides and kill the pines. Where an acre of currant or gooseberry plants thus may endanger extensive pine forests, the cost has been found justified by the value of the pine protected.

Explanation of Plates 12–15

Plate 12-A. (Upper)—Bulldozer with special brush rake.

Plate 12-B. (Lower)—Bulldozer clearing brush.

Plate 13.—Areas cleared with bulldozer showing brush piles to be burned.

Plate 14-A. (Upper)—Grass established on bulldozer area one year after clearing.

Plate 14-B. (Lower)—Area *x* before clearing.

Plate 15-A. (Upper)—Area *x* after clearing, showing windrows of brush.

Plate 15-B. (Lower)— Area *x* a year later with grasses becoming established.

Plate 14-B and Plate 15-A and B show the same area before, during, and after, clearing, all photographs by the Division of Plant Disease Control, U. S. Bureau of Entomology and Plant Quarantine.

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STRIPPING BRUSHFIELDS FOR PLANTING IN CALIFORNIA

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The development of machinery for clearing lanes through dense brush has been an important step in reforestation of California brushfields. The equipment has been particularly designed to meet the specific requirements of the planting job.

The brushfields which planting is expected to reclaim prevail mainly as a result of fire on good timber sites in the pine belt. The fields are covered in varying density by such brush as manzanita (*Arctostaphylos* spp.), snowbrush (*Ceanothus* spp.), chinquapin (*Castanopsis* spp.), and cherry (*Prunus* spp.) frequently 5 feet or more in height and with stem diameters up to 4 inches at the ground line. Successful establishment of trees has required the clearing of lanes through this brush to facilitate planting and to release the transplants partially from subsequent competition. Usually the brush is so dense that material uprooted in the lanes must literally be forced into the shrubs on either side to get it out of the way. Abundant power is required to do this, to uproot the heavy brush, and to dislodge rocks from the soil, hence the machinery developed is of both heavy and rugged construction.

The most efficient machine so far used in the preparation of planting sites is the Plumas Brush Stripper, designed and first used by Supervisor David N. Rogers and his head mechanic on the Plumas National Forest. This machine illustrated by Plate 16 differs from others tested in that the uprooting device follows the power unit instead of preceding it. The original model, built in 1936, was tested by extensive field use for two years and at the end of that time such minor changes in design as deemed necessary were made. In the spring of 1938 a new machine embodying the changes was purchased under bid for $675.

The Plumas Brush Stripper clears a lane from 6 to 7 feet wide. It weighs approximately four tons and is drawn by a 90 H.P. tractor, the combined unit being designed to negotiate grades up to 35 per cent. Two men are required for operation, the tractor driver and a man who rides on the tractor and manipulates the hoist which adjusts the height of the stripper blade. The lower edge of the blade is ordinarily set below the ground surface to assure removal of the sprout-producing brush stools. The latest test of this equipment in representative brush and ground conditions on the Shasta National Forest resulted in completion of 191 miles of strip at an average cost of $7.58 per mile including protective fire lines. This cost figure includes labor, supervision, operation, and rental of equipment.

Tests of other machinery have also been made in the California brushfields. Small trailbuilders (50–55 H.P.) opened lanes at an approximate cost of $40 per mile; large trailbuilders operated at around $15 per mile, and one commercial brush-ripper completed strips at $20 per mile. This last-named machine, while operating satisfactorily,

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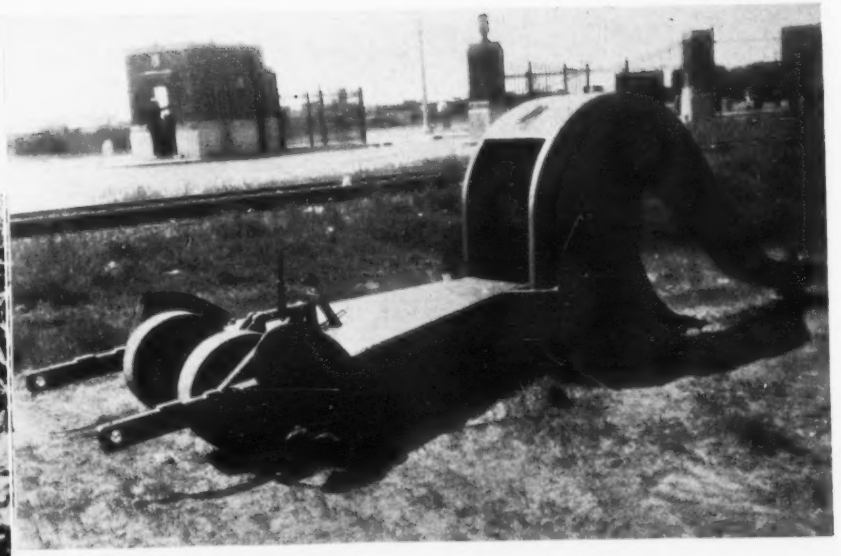

A. (*Right*)—Plumas Brush Stripper, 1938 Model.
B. (*Left*)—Lane cleared through dense brush by Plumas Brush Stripper (Earlier model) Photographs by U. S. Forest Service.

cleared a strip twice as wide as was needed for planting and was therefore not adapted for that job although for other purposes requiring a wider opening it might be economical. From the standpoint of efficiency and economy the Plumas Brush Stripper is now regarded as the best machine for clearing lanes through brushfields preparatory to planting.

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LATE AUTUMN FOOD OF THE SHARP-TAILED GROUSE IN WESTERN NEBRASKA

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This article treats of the food of the Sharp-tailed Grouse in western Nebraska during late autumn, following a season of severe drought. Early in November, 1934, an illegal shipment of 56 game birds was seized by authorities at Truckee, California. It is believed that these birds had been shot late in October, probably in the vicinity of Broadwater, Morrill County, Nebraska. On December 22, 1934, these birds were delivered to the Department of Entomology of the College of Agriculture, University of Nebraska, by Frank B. O'Connell, Chief Conservation Officer and Secretary of the Game, Forestation, and Parks Commission of Nebraska, for purposes of dissection and analysis of their food. The shipment included 29 Sharp-tailed Grouse (*Pediocetes phasianellus jamesi*), many of them birds of the year, analyses of which are here reported upon.

All of these birds were frozen solidly when delivered. They were allowed to thaw and relax, when the crops and gizzards were dissected out by Watson E. Beed, who preserved their contents in separately numbered vials of 70 per cent alcohol. In analyzing the contents of the crops and gizzards, the procedure was as follows: All plant leaves were separated from the saturated mixture in the 70 per cent alcohol, identified in that state if possible, and then set aside to dry. The alcohol was poured off from the remainder of the mixture, and this residue also dried. The dry contents of each crop and gizzard were then separated into their constituent elements or foods, the weights of each of which were taken separately, to 0.001 gram.

Broadwater, Morrill County, where, it is believed, these birds were shot, lies in the extreme western part of Nebraska, in the North Platte Basin. The county is in the Great Plains, in the division known as the High Plains. Broadwater itself is situated on the low terrace to the north of the North Platte River where about half of the land is under irrigation. The country slopes rather rapidly upward from these bottom lands, where cultivation is extensive, to the rough broken territory above, where only grazing takes place, and which is probably the area where these grouse normally find a most suitable habitat. The native vegetation on the low terrace is mainly sand-grass (*Calamovilfa longifolia*) and needle-grass (*Stipa* spp.), which are replaced in the higher land by buffalo grass (*Buchloë dactyloides*), western wheat-grass (*Agropyron smithii*), and gramas (*Bouteloua* spp.).

The writers wish to acknowledge indebtedness to Raymond Kinch, Seed Analyst at the Nebraska Department of Agriculture, and N. F. Peterson, of the Department of Agronomy of the College of Agriculture, for assistance in identification of certain seeds, and also to Edward C. Klostermeyer for assistance in both the insect and seed identifica-

[1] Published with the approval of the Director as Paper No. 210, Journal Series, Nebraska Agricultural Experiment Station.

TABLE 1

A SUMMARY OF THE LATE AUTUMN FOOD OF THE SHARP-TAILED GROUSE

Type of Food	Class Frequency Indices			Weight Indices		
	Percentage of Individuals in Which Identified			Percentage of Total Food Material (Based on Dry Weight)		
	Crops	Gizzards	Birds	Crops	Gizzards	Birds
Vegetable Matter	86.2	100.0	100.0	99.77	98.83	99.30
Leaves	86.2	96.5	96.5	72.77	19.24	44.85
Seeds	44.8	100.0	100.0	24.14	50.44	37.87
Vegetable debris	82.8	100.0	100.0	2.86	29.15	16.58
Animal Matter	37.9	75.9	82.8	0.22	0.36	0.28
Insects	24.1	51.7	58.6	0.16	0.32	0.23
Grouse feathers	24.1	17.2	34.5	0.06	0.04	0.05
Animal debris	—	6.9	6.9	—	0.01	trace
Grit	—	10.3	10.3	—	0.82	0.42

TABLE 2

THE FOURTEEN MOST IMPORTANT FOOD ITEMS

Food Item	Percentage of Total Food Material (Based on Dry Weight)	Number of Individuals in Which Identified
Common prairie rose seeds	16.36	29
White clover leaves	16.17	20
Common dandelion seeds	14.24	19
Sweet clover leaves	13.34	11
Common dandelion leaves	7.34	16
Wolfberry seeds	2.76	13
Grass leaves	2.17	29
Climbing poison ivy seeds	2.00	6
Wolfberry leaves	1.54	8
Leaves not identified	1.48	15
Prairie ground cherry leaves	1.46	4
Prairie ground cherry seeds	1.44	5
Knotweed seeds	1.07	12
Seeds not identified	0.71	20

TABLE 3

THE EIGHT MOST UTILIZED FOOD PLANTS

Food Plant	Percentage of Total Food Material (Based on Dry Weight)	Probable Bulk Ranking (Estimated)
Common dandelion	21.58	1
Common prairie rose	16.53	4
White clover	16.17	2
Sweet clover	13.41	3
Wolfberry	4.30	5
Prairie ground cherry	2.90	6
Grass (not further identified)	2.17	7
Climbing poison ivy	2.00	8

tions. Acknowledgment is also due to Dr. Eloise B. Cram then of the Bureau of Animal Industry, United States Department of Agriculture, for identification of a nematode parasite (*Gongylonema* sp.) found in the crops of 4 grouse, and of another (*Seurocyrnea* sp.,? *colini*) from the gizzard of a fifth grouse.

VEGETABLE MATTER[2]

Vegetable matter comprised 99.77 per cent of the material found in the crops, 98.83 per cent of that found in the gizzards, and 99.3 per cent of the total food recovered from the birds. Plant seeds were found in all of the birds and leaves were present in all but one. Leaves made up 44.85 per cent of the total food, while seeds constituted 37.87 per cent. As would be anticipated, the bulk of the leaves was present in the crops, while most of the seeds were in the gizzards.

The common dandelion (*Leontodon taraxacum*) ranked first, constituting 21.58 per cent of the total food. Very probably this late autumn predominance of dandelion as grouse food is correlated with the drought of the preceding summer, which did not affect this species so seriously as it did many other herbs. Among the important food items, as listed in Table 2, dandelion seeds were in third, and the leaves in fifth, place. The seeds were found in 19 birds, making up 23.98 per cent of the crop contents, 5.32 per cent of the gizzard contents, and 14.24 per cent of the total food. The leaves, appearing in 16 birds, comprised 12.2 per cent of the crop contents, 2.88 per cent of the gizzard contents, and 7.34 per cent of the total food.

The common prairie rose (*Rosa pratincola*) was the next most important food plant, composing 16.53 per cent of all the material eaten. Seeds formed the larger part, being utilized to the extent of 31.33 per cent of the gizzard contents and 16.36 per cent of all of the food. No rose seeds appeared in the crops, yet these seeds ranked first among the food items eaten. Leaves were present in only 2 birds and formed only a minute part (0.17 per cent) of the weight of the total food consumed.

White clover (*Trifolium repens*) was the third most important food plant. Only the leaves were eaten and these to the extent of 16.17 per cent of the diet. White clover leaves ranked second among the important food items and were present in 20 of the birds, forming 27.02 per cent of the crop contents and 6.22 per cent of the gizzard contents.

Sweet clovers (*Melilotus alba* and *M. officinalis*), fourth in rank among the food plants, comprised 13.41 per cent of the total food. The leaves made up almost all of this, constituting 21.15 per cent of the crop contents, 6.19 per cent of the gizzard contents, and 13.34 per cent of the total diet. Sweet clover leaves were taken by 11 birds, while the seeds were eaten by only 3.

Wolfberry (*Symphoricarpos occidentalis*) was next in importance, composing 4.30 per cent of the total food, with the leaves making up 1.54 per cent and the seeds 2.76 per cent. The seeds comprised 5.28 per cent of the

[2] The percentage of each vegetable food item in the total vegetable material is not given because that ratio is very similar to, and often duplicates, the percentage of each vegetable food item in the total food material. This is due to the almost completely vegetarian diet of the grouse examined.

gizzard contents and the leaves 3.23 per cent of the crop contents. No leaves were found in the gizzards and no seeds in the crops. Among all food items wolfberry seeds ranked sixth, with 13 appearances and the leaves ninth, with 8 appearances.

Prairie ground cherry (*Physalis lanceolata*) was sixth among the food plants, with the leaves appearing in 4 birds and the seeds in 5. The leaves and seeds were in eleventh and twelfth places, respectively, among individual food items. This plant constituted 2.90 per cent of the total food, the leaves comprising 1.46 per cent of all food, 3.03 per cent of the crop contents, and 0.01 per cent of the gizzard contents. No seeds were found in the crops, but 2.75 per cent of the gizzard contents were prairie ground cherry seeds which formed 1.44 per cent of the total weight of food.

Grass leaves (not further identified), in seventh place among the food plants, composed 2.17 per cent of the total food recovered, forming 1.87 per cent of the material in the crops and 2.44 per cent in that of the gizzards. Seeds of several grasses were present only in traces, that is less than 0.005 per cent of the total food material. All were found in the gizzards. The following were identified: barnyard-grass (*Echinochloa crus-galli*), oat-grass (*Arrhenatherum elatius*), squirrel-tail grass (*Hordeum jubatum*), green foxtail (*Chaetochloa viridis*), and panic-grass (*Panicum* sp.). Each of these appeared only once, while grass leaves in small quantities were present in all of the birds.

Climbing poison ivy (*Toxicodendron radicans*) made up 2.00 per cent of the total food and placed eighth among the food plants. Only the seeds were recovered and they were found in only 6 gizzards, forming 3.84 per cent of the total material in the gizzards.

Leaves not identified appeared in 15 birds and composed 1.51 per cent of the material in the crops, 1.44 per cent of that in the gizzards, and 1.48 per cent of the total food. Seeds not identified were present in 20 birds, constituting 0.16 per cent of the crop contents, 1.22 per cent of the gizzard contents, and 0.71 per cent of the entire diet.

Knotweed (*Polygonum aviculare*), with the leaves present in 4 birds and the seeds in 12, formed 1.15 per cent of the total food. Leaves were not present in the gizzards, but formed 2.25 per cent of all the crop contents and 1.07 per cent of the total diet. The seeds were present only in the gizzards, and to the extent of 0.15 per cent, comprising 0.08 per cent of the entire food.

Leaves of other plants combined to form only 0.11 per cent of the total food, and 0.22 per cent of the crop contents. No leaves were contained in the gizzards. Plants in this miscellaneous group and their number of occurrences were: alfalfa (*Medicago sativa*) and knotweed (*Polygonum* sp.), 2; and smartweed (*Persicaria pennsylvanica*) and western wheat-grass (*Agropyron smithii*), 1.

Seeds which constituted only traces and their number of appearances were: prairie sunflower (*Helianthus petiolaris*) and knotweed (*Polygonum* sp.), 3; smartweed (*P. pennsylvanica*) and lesser ragweed (*Ambrosia elatior*), 2; and black nightshade (*Solanum nigrum*) and white mulberry (*Morus alba*), 1.

Vegetable debris consisted in the

main of finely ground material which was extremely difficult to separate, and which if it had been segregated would not have altered the final results to any appreciable degree. Besides this unseparated vegetable material, a few other items mentioned below, of which only traces were present, also were included in this allocation because in quantity they did not merit a separate classification. Vegetable debris constituted 16.58 per cent of the total food, involving 2.86 per cent of the crop contents and 29.15 per cent of the gizzard contents. Miscellaneous items grouped with vegetable debris, which together constituted 0.03 per cent of the crop contents, 0.69 per cent of the gizzard contents, and 0.37 per cent of the total food material, with their number of occurrences were: bits of paper, 4; straw, 2; and variable rose-gall (*Rhodites variabilis* on *Rosa pratincola*), pea stem-gall (*Aylax pisum* on *Lygodesmia juncea*), and bits of black thread, 1.

Animal Matter

Animal matter in its entirety composed so small an amount of the total food, 0.28 per cent, as to be almost negligible. Crops contained 0.22 per cent and gizzards 0.36 per cent of animal matter. Because they are so minute, the percentages of the various animal foods are not itemized.

Insects constituted the larger part of the animal matter, to the extent of 0.23 per cent of the total food. Those found, with their number of occurrences, were: unidentified insect remains, 13; ladybird beetles (*Hippodamia convergens*, and *H.* sp.), 6; grasshoppers (Acrididae, including *Melanoplus* sp.), 4; and Colorado dock beetle (*Gastroidea dissimilis*), moon-spotted ladybird beetle (*Hippodamia lunato-maculata apicalis*), weevil (Curculionidae), ladybird beetle (not further identified), tarnished plant-bug (*Lygus pratensis*), and stink-bugs (*Aelia americana* and *Liodermion uhleri*), 1.

Grouse feathers appeared in 10 birds. These were probably swallowed during preening. Animal debris, present in 2 birds, made up only a trace of the total food.

Mineral Matter

Grit was the sole mineral matter present, and it appeared in only 3 birds to constitute 0.42 per cent of the total ingested material. It was not present in the crops, but made up 0.82 per cent of the gizzard contents.

Summary

Evident throughout these analyses was the necessity of examining both crops and gizzards in order to get a true picture of the types and quantities of food eaten. The bulk of the seeds was found in the gizzards and the largest part of the leaves in the crops. Data in Table 1 indicate that approximately four times as much by weight of leaves was in the crops as in the gizzards and twice as much by weight of seeds in the gizzards as in the crops. Vegetation (99.30 per cent) made up almost the entire diet of the Sharp-tailed Grouse; 44.85 per cent consisted of leaves, 37.87 per cent of seeds, and 16.58 per cent was designated as vegetable debris. Of the separable vegetable matter, common dandelion, common prairie rose, white clover, and sweet clover together constituted 67.69 per cent of the total

food. It was unexpected that an introduced food plant, the common dandelion, should top the list, composing about one-fifth of the entire food. Legumes—white clover and sweet clover—comprised approximately three-tenths of the total food. Animal matter made up so small a proportion of the total food, 0.28 per cent, that it seems insignificant. Insects constituted the bulk of the animal matter to the extent of 0.23 per cent of the total food, with grasshoppers, ladybird beetles, and stink-bugs most represented. Mineral matter, entirely grit, was found in the gizzards of only 3 birds, and constituted 0.42 per cent of the total food material.

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THE GREAT HORNED OWL AS AN INDICATOR OF VULNERABILITY IN PREY POPULATIONS[1]

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In the course of population studies of wild vertebrates recently carried on in north-central United States,[2] nearly 5,000 pellets of the great horned owl (*Bubo virginianus*) have been collected, largely from areas under regular observation over a period of years. Although the analyses of a minor percentage of these pellets have not been completed, a preliminary paper on some of the earlier food habits data has been published (Errington, 1932b), and many of the other data in hand are organized to a sufficient degree to show some interesting trends (Errington, Frances Hamerstrom and F. N. Hamerstrom, Jr., unpublished).

Comparisons of changes in representation of given prey species in horned owl diet with data on the prey populations have been especially illuminating. For certain forms, it has become apparent that overpopulation of habitats, evictions, seasonal or climatic phenomena, agricultural practices, and miscellaneous accidents and emergencies all may be factors strongly influencing vulnerability to predation by the owls.

Vulnerability of Populations as Reflected by Horned Owl Pressure

One of the first indications of population vulnerability to be noticed was the pronounced increase of representation of the bob-white quail (*Colinus virginianus*) in horned owl diet as quail populations exceeded the capacity of accommodation of their winter habitats (Errington and Hamerstrom, 1936; Errington, 1937c).

Less voluminous and conclusive but similarly indicative are data from south-central Wisconsin and south-central Minnesota on the relation of insecurity of population levels of the ruffed grouse (*Bonasa umbellus*) in marginal environment to horned owl pressure (Errington, 1937b, and unpublished).

King (1937) recorded for the winter of 1933–34, on his Cloquet study area in north-central Minnesota, a top-heavy fall population of grouse that by April had been reduced to approximately the spring density of the two preceding years. The reduction was accompanied by the most severe predation observed on the area during seven years of intensive study; no horned owl pellets contemporaneous in deposition with the period of heaviest grouse losses were analyzed, but ruffed grouse remains in two of 60 spring pellets in ad-

[1] Journal Paper no. J562 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 330.

[2] Wisconsin Quail Investigation, 1929–32, established at the University of Wisconsin by the Sporting Arms and Ammunition Manufacturer's Institute and the U. S. Biological Survey; cooperative wildlife research program of Iowa State College and Iowa Fish and Game Commission, 1932–35, with the aid of financial contributions from J. N. ("Ding") Darling. Particular acknowledgment is made of help with specimen material by the Division of Food Habits Research of the Biological Survey.

dition to field evidence may suggest that this overpopulation of birds was decidedly vulnerable to horned owls among other predators.

Few population data on the introduced ring-necked pheasant (*Phasianus colchicus torquatus*) and the Hungarian partridge (*Perdix perdix*) are available for the same seasons and from the same localities where work on the food habits of the horned owl was done. Impressions from field studies, however, were that the pheasant population seemed to have reached a high level in northwest Iowa in the fall of 1932, whereas population densities of the Hungarian partridge seemed to be moderately low, as they had been for some years.

By the fall of 1933, the pheasants were apparently less numerous than the year before, although their densities were still high. The partridge populations seemed to have shown an increase. Representation of pheasant remains in 46 or 20.5% of 224 horned owl pellets in the winter of 1933–34 and partridge remains in 12 or 5.4% appears to reflect rather well the comparative vulnerability of these two populations.

The spring and summer of 1934 was one of extreme drought, and, though it is not at all clear how much this may have increased the general vulnerability of pheasants, a rise in representation of partridges in the diet of the red fox (*Vulpes regalis*) was thought to be associated both with higher partridge densities and with increased vulnerability due to drought (Errington, 1937a). Of 147 horned owl pellets from spring and summer, 1934, 54 or 36.7% and 14 or 9.5% contained pheasant and partridge remains, respectively.

By the winter of 1934–35, pheasants were present in northwest Iowa in considerable abundance but their numbers were evidently lower than for the preceding two winters. The representation of pheasant remains in but 10 or 6.4% of 156 horned owl pellets suggests that these birds may have been wintering at densities near some sort of threshold of security. The spring and summer representation for 1935 was higher—in 33 or 23.1% of 143 pellets—but at this time of year predation on gallinaceous birds studied seems to be more in proportion to their actual numbers than in winter.

Hungarian partridge densities in the winter of 1934–35 and the summer of 1935 were not known to differ much from those of the previous year, nor did there seem to be any significant change in horned owl pressure upon them. For the winter, seven or 4.5% of 156 pellets contained partridge remains; for spring and summer, 11 or 7.7% of 143 pellets.

Among the mammals, the muskrat has been the subject of research in Iowa in late years, from the standpoints of both population and predation. The studies have not all been carried on in areas hunted over by horned owls, but some of them have, and these reveal striking connections between predator food habits and vulnerability of prey.

The muskrat populations in the areas under observation in northwest Iowa were in the early stages of recovery from a drought when the Iowa cooperative program was begun in 1932. Aided by a closed trapping season during the fall and winter of 1933–34 and favorable breeding conditions during the summers of 1933 and 1934, the

animals reached exceptional abundance by the trapping season of 1934–35, when the Mud Lake Fur Farm alone reported a catch of 2,528 muskrats or about 8.5 per acre from about 300 acreas of privately owned marsh near Ruthven, Iowa (letter, Joe Kautzky, Jr., March 23, 1938).

Despite the patently high fall density for 1934 and a probable density close to five muskrats per acre in the fall of 1933 when no trapping was done, 209 horned owl pellets collected from a wooded island in Mud Lake from early spring, 1933, to early spring, 1935, contained no muskrat remains, which seems explainable in terms of the excellence of the habitat even for such large numbers of animals.

In late spring and early summer, 1935, stands of Cyperaceae covering roughly one-third of Mud Lake died out from some undetermined cause, and this was followed by the horned owls responding in a spectacular manner to the consequent exposure of a large part of the muskrat population. Of 43 pellets from April and May, one of those from late May contained muskrat remains; then five of 16 pellets from June showed this item; and also eight of 12 July pellets. In the eight muskrat-containing pellets from July, remains of one adult and 11 young individuals were distinguished. The population was at perhaps half the density that the marsh had accommodated with evident security the year before, yet it apparently became conspicuously vulnerable by reason of drastic changes in a very important constituent of its environment—the cover.

From woods bordering muskrat-occupied streams away from Mud Lake but within a radius of 15 miles, 441 horned owl pellets representing food habits from fall, 1933, to summer, 1935, were collected; nine or 2.0% of these contained muskrat remains. Six representations were noted in one lot of 32 pellets from the West Des Moines River northwest of Emmetsburg and two more in 168 pellets from elsewhere along the River, or a total of eight in 200 pellets for the fall and winter of 1933–34. It cannot be said positively that this horned owl pressure was the result of locally overpopulated muskrat habitats but, in view of the evidence, such is believed to be the case.

DIFFICULTLY EVALUATED TYPES OF HORNED OWL PRESSURE UPON PREY POPULATIONS

Of the prey species referred to in the preceding section, the bob-white has received by far the most study in north-central states and has yielded population data that permit close comparison with food habits records for horned owls and other predators. Losses to horned owls of wintering bob-whites in overpopulated coverts have frequently been extreme (Errington and Hamerstrom, 1936; Errington, 1937c), but overpopulations have not invariably been attended by severe horned owl pressure, even when horned owls were plentiful in the vicinity.

Decreased horned owl pressure upon insecurely situated northern bob-white populations usually has not meant perceptibly decreased pressure from predators collectively, however, as the losses from predation tend to be in proportion to the vulnerability of the bob-white population, whether through the medium of one or of several predatory

species or in the presence of some or in the absence of others. The reasons are seldom plain why increased pressure from foxes, hawks, or lesser predators should often compensate for relieved horned owl pressure upon vulnerable bob-whites, but the existence of such compensatory trends should not be overlooked.

Interplay of population phenomena of species that constitute staple prey for predators—the so-called buffers—doubtless has more or less influence on the food habits of the horned owl, though here again we know too little of what happens, and why it happens, to draw many conclusions.

The 1934 drought was attended by a substantial decrease in representation of mice in the diet of the red fox (Errington, 1937a) coincident with a heavy increase of these rodents in horned owl diet, but it is not believed that the food habits of either predator had in this case any real influence on those of the other.

In the north-central states observational areas, common predatory birds and mammals seldom appear to be closely dependent upon any one or any few food animals; if one staple becomes largely unavailable, the predators usually have little apparent difficulty in turning to other abundant and available species for their chief foods. Some of the most active predators frequently seem to live at densities about as high as they themselves will tolerate or can maintain and still not utilize more than a minor proportion of the animals available to them as prey. Even at unusually low densities, some prey populations may be sufficiently abundant and available to serve as staple foods for predators much as they did when their densities were higher. For example, the cottontail rabbit (*Sylvilagus floridanus*) population on an area near Prairie du Sac, Wisconsin, was judged to be only about one-third "normal" during the winter of 1936–37, but cottontail remains were represented in the pellets from an average population of horned owls in about the same proportions that they had been for many years.

The findings of Kalabuchov and Raewski from mouse studies in the North Caucasus (Gause, 1934) and indirect data on the cottontail rabbit in southern Wisconsin suggest that thresholds of security for "buffer" populations are likely to occur at low levels compared to levels typically existing in given habitats. Predation on populations of this type may then be largely in proportion to population (McAtee, 1932) or perhaps in proportion to overpopulation to the extent that populations may consist essentially of overpopulations (Errington, 1935c).

Similarly, many species of birds that concentrate along their migratory routes are readily taken by predators during times when they may be present in conspicuous and available abundance, and these seem to be vulnerable largely in proportion to their numbers.

Other species seem for imperfectly ascertained reasons to be vulnerable out of all proportion to their numbers. Field-living barn rats (*Rattus norvegicus*) wintering in southern Wisconsin appeared to be highly insecure at all observed population levels and, under local conditions, suffered practically annihilative pressure from owls (Errington, 1935a).

Of native animals, screech owls (*Otus*

asio), flying squirrels (*Glaucomys volans*), and weasels (*Mustela* spp.) seem to suffer disproportionately heavy pressure from large owls, but the first two on the Iowa and Wisconsin study areas may have been more abundant than was thought. Snow trails of weasels, however, often indicated densities of perhaps one or two per square mile in localities from which 1% or more of the horned owl pellets contained weasel remains.

For What Prey Types Does Horned Owl Pressure Show Most Promise as an Index of Vulnerability?

It may be seen so far that, within the limits of accommodation of their habitats, winter populations of the northern bob-white have been at ordinary densities relatively secure from simple predation but have become vulnerable to native enemies chiefly as their coverts have become overcrowded with their own kind. To some extent this sort of relationship may also hold true for other less gregarious gallinaceous birds. At another extreme, of some populations—notably of gregarious migratory birds or of mammalian "buffers"—it may virtually be said that they have been vulnerable to predators at all ordinary densities.

Hence, heavy predator pressure upon adults of species in the first of these categories may signify a state of population unbalance or serious emergency. Starvation does not necessarily render bob-whites appreciably more vulnerable to horned owls except insofar as it may intensify overcrowding in habitats still well stocked with food (Errington, 1936), but eviction of bob-white coveys following such human activities as "cleaning up" of brushy cover, burning of brush piles and ground vegetation, etc., is often attended by substantial losses. On the other hand, not all of the natural factors and habitat changes one would judge to be adverse actually do have lethal significance, as may be brought out by the use of varied investigational approaches. Reliable population data are important in the evaluation of many ecological phenomena, but, combined with population data or in their absence, indirect evidence as from predation data may frequently be of pronounced utility.

Predator pressure on species that are preyed upon to much the same extent whether at high levels or low, and whether in average or critical times, may reveal little about the prey species except that certain animals were available to the predators and, occasionally, that certain animals were obviously plentiful. In view of the fact that these same staple prey animals usually make up the bulk of predator diet, many of the items listed in connection with food habits work may not ordinarily have particular significance that can be recognized at this stage of our knowledge.

It seems, therefore, that prey species taken rather incidentally by predators are those of which unusual representation in predator diets may give the greatest promise of providing added insight into the functioning of population mechanisms. The northern bob-white "... being rarely if ever staple prey for anything, may perhaps be regarded as but a side dish for hungry flesh-eaters, entirely acceptable if conveni-

ently available, easily to be dispensed with if not" (Errington and Hamerstrom, 1936, p. 380); and in addition to this example are doubtless unknown numbers of other species for which striking changes in vulnerability may to an investigator be the broadest sort of hint of current population status. Species holding territories or intolerant of concentrations of their own kinds above thresholds of security or other more or less well-defined population strata occur with some frequency among higher vertebrates, and many of these would appear logical subjects of inquiry at least partially through studies of the food habits of their predatory enemies.

Of native predators upon small to medium-sized higher vertebrates in north-central states, the horned owl is both an efficient hunter and a general feeder. It is in many respects an automaton, and its hunting behavior is sufficiently stereotyped so that it appears to take its food just about in order of convenience (Errington, 1932c). And while the horned owl is not an infallible indicator of vulnerability for specific prey populations, it is believed to be the nearest approach to such an indicator of any predator we have yet worked with. Moreover, it is widely distributed, fairly common locally, and may be studied with relative ease.

THE FEEDING OF THE GREAT HORNED OWL

The horned owl may on occasion hunt during daylight hours as well as at night. Forbush (1927, p. 225) described it quartering over a meadow like a marsh hawk; it may seize a bird in the air or swoop down upon a running cottontail; it may watch for prey from posts and other positions of vantage or it may sidle up to sleepy poultry in trees or on open roosts. Despite its large size, it is capable of surprisingly swift flight, which surely contributes to its efficiency as a predator; Forbush (1927, pp. 225–226) has written, "When the bird strikes a victim, the force of the blow tends to bend the legs, contract the tendons and drive the claws into a vital part. In addition to this the powerful muscles of the legs are brought into play to force the talons home. Thus its speed, weight, and muscular power all combine to give the bird the force to overcome animals many times its own weight."

For all of its hunting prowess, nevertheless, the horned owl tends to be lethargic about killing in excess of immediate needs except when prey may be unusually available. As a rule, a rabbit or victim of similar size is largely consumed before another is taken, though more than one owl may participate in the feeding or one carcass may serve for several meals.

In feeding, horned owls observed in captivity and in the wild swallowed the smaller mammals and birds whole or first decapitated; and larger prey in the most convenient pieces they were able to tear loose (Plate 17-A, B, C). Scarcely any attempts were made at skinning or plucking other than the pulling out of primaries and tail feathers and the eating away of flesh from tough hide. The manner of feeding of captive owls was influenced by the condition of the carcass, whether cold or freshly killed: "A raptor's clutch on dying prey elicits on the part of the raptor a series of reflexes not confined to

the killing; responses manifested by jerking out the primaries, tugging at the head, and 'mouthing,' all more or less bound up with the possession of something alive or very recently alive. Horned owls . . . given live rats, ground squirrels, quail, or young chickens regularly ate the heads first; if offered the same prey dead and cold they often started eating almost any place on the carcass. . . . Much irregularity in the plucking of primaries of dead birds was also noted" (Errington, 1932a).

Hand-reared captive horned owls with which experiments were conducted seemed not to acquire the strength and facility of feeding normal to adults living in the wild, but the latter typically bolted lumps of flesh and bone torn from prey the size of cottontail rabbits. From the appearance of the heavy broken bones in stomachs and pellets (Plate 17-D) and from the impression gained through close-range watching of adults feeding their young, it seems plain that sizeable portions of prey carcasses are half-sheared, half-wrenched free, as needed. Heavier bones of larger prey, as adult striped skunks (*Mephitis*), geese, turkeys, etc., may be too difficult either to break or to swallow, but quantities of fur or feathers are freely eaten. Whether stomach and intestinal viscera of victims will be eaten seems to depend upon their bulk and the habits of individual owls.

Carrion-feeding on the part of horned owls has been observed on various occasions. Reference has been made to a horned owl feeding on a skinned cow carcass (Errington, 1932c), and the owls sometimes show interest in trap baits. Carcasses of rabbits or other known horned owl victims may be left about in the woods and later revisited by horned owls, perhaps by the original killers, perhaps by others. Satisfied owls in possession of uneaten pieces of prey may simply sit upon them until again hungry. I have no evidence of horned owls eating putrid meat except when forced by hunger, although sour-smelling items covered with fly eggs or newly hatched larvae are often eaten or fed to the young.

In short, the horned owl is particular neither as concerns what it kills nor what it eats. Exceptions notwithstanding, nearly all of its food is owl-killed prey, and nearly all of its prey sooner or later is eaten.

DIGESTION AND PELLET FORMATION

Reed and Reed (1928) found that gastric secretion in the great horned owl was apparently not profuse; that peptic activity was "generally about three times as potent as that of dog gastric juice at comparable stages of digestion." And: "No free acidity was found in gastric contents at any stage of digestion nor in extracts of pellets . . . The absence of free acidity possibly accounts for the fact that the bones of the pellet masses showed no evidence of corrosion. The ends were sometimes crushed and broken, but this apparently occurred before swallowing . . . The broken edges were always sharp and clean and when examined under a low-power microscope showed no evidence of corrosive action. Furthermore, pigment in hair and feathers appeared to be undisturbed."

These authors also state: "Observations made by killing during digestion and examining the gastric contents

showed that there was no mixing of materials after swallowing, as small masses of different colored hair retained their original relative positions. The outside of the pellets consisted of hair and bones cleanly freed from digestible materials, while there was progressively less digestion in evidence toward the center of the mass." (C of Plate 18 represents a fair example of an unbroken pellet made up of remains of a medium-sized mammal.)

To this it may be added that one end of a pellet often shows less digestion than the other, as a result of feeding at different times. Now and then, some animal like a mouse may be eaten shortly before the ejection of the pellet, to be partially imbedded in quite undigested condition in the end of the main pellet mass. Occasionally, some portion of a victim may be swallowed that doesn't get into the stomach proper; and pellets made up of remains of rabbits and large birds may be encountered to which are attached undigested feet, wings, tails, or other awkwardly manageable pieces. This has been demonstrated experimentally, as well.

Owl pellets—consisting of feathers, fur, scales, bones, chitin and other undigested residue from previous meals—are ejected orally, there being, as Reed and Reed indicate, "a mechanical bar to the passage of anything but finely divided material from the stomach to the intestine." Horned owls ordinarily eject pellets within 24 hours after feeding (Reed, 1925; Errington, 1930) but do not conform strictly to any time schedules in so doing.

How much the ejection of pellets may be an act within the conscious control of the owl is problematical. A pair of skinned cat scapulae fed to a captive horned owl were ejected, with the readily accessible meat digested, within an estimated period of about five hours; these wide, flat, rather sharp-edged bones probably became increasingly uncomfortable to retain after the digestion of their fleshy padding.

"Apparently, a mechanism similar to vomiting in higher forms is involved in regurgitation, since the subjects show evidence of nausea for fifteen to twenty minutes before the mass [pellet] is discharged. . . . In spite of the feeble gastric motility during digestion, it is apparent that the musculature is sufficiently active to discharge large masses. No information is available at present as to the nature of the reflex mechanism involved in the process" (Reed and Reed, 1928).

At times when a small residuum of material is retained in the stomach after ejection of the main pellet, this portion may later be ejected as a separate pellet or added to the pellet of the next day, or it may be voided in the feces as finely ground fur and feather debris. It was observed experimentally that individual horned owls, when given food containing only small amounts of pellet-forming material, would pass all the waste out in the feces; and the occurrence of variable quantities of broken-down fur in feces may be noted at practically any season under the roost trees of horned owls in the wild. Some individuals seemingly do not become unpleasantly conscious of pellets of considerable size for two or three days, finally unloading pellets of astonishing dimensions; others may eject pellets daily from scanty bulk.

In the case of young owls, pellets may be ejected after the first feeding (Errington, 1932a; Sumner, 1933), or not until the birds are days or even weeks old (Errington, 1930). Typically, the owlets appear to eject pellets from the time that they are fed pellet-forming substance.

Variations in treatment of food residues in stomachs may be observed not only in the same species but in the same individual. Some of this may be attributed to such things as greater calcium demands of birds at early ages, "a recently hatched horned owlet ejecting at the start boneless pellets on practically any rough diet" (Errington, 1932a). On the whole, bones in pellets showed less digestion as the growth of the owlets progressed. Sumner (1933), however, reported that bone particles "appeared even in the pellet of a day-old barn owl just removed from the nest."

In pellets from adult horned owls, the cartilaginous bone ends of amphibia and of immature mammals and birds have usually disappeared and the soft bones themselves have become more or less reduced (Plate 18-A; Plate 20). Skeletons of adult higher vertebrates of small-sized species may be reduced considerably by digestion in a horned owl stomach but seldom to the point of disappearing completely. While Reed and Reed (1928) found no evidence of bone corrosion, Sumner (1933) has written regarding pellets of barn owls (*Tyto alba pratincola*) as well as horned owls: "Many long bones and some skulls were intact, but examination under the microscope indicated a slight wearing of the broken shards when compared with freshly shattered fragments of the same bones." The length of time that a bone may be subjected to digestive action has a bearing upon the degree to which bones may be corroded, as may also the amount of movement of the stomach contents.

In the handling of hundreds of pellets resulting from the experimental feeding of captive horned owls and thousands gathered from retreats of wild birds, large numbers have been found that revealed decided evidence of mechanical action. Frequently, pellets dried for storage consisted of mouse, cottontail, and other bones in a furry matrix reduced virtually to powder; in others, very little save butts and debris remained of feathers ingested (Plate 18-D, E).

Feathers tend to be ground up more than fur in horned owl pellets probably because much avian debris is less cohesive than mammalian (compare A and B of Plate 19). Feathers withstand digestion in nearly intact form when packed in protected places about thoracic vertebrae or if they have worked into the foramen magnum or eye sockets of an uncrushed skull. Fur that is crowded into bone cavities also comes through in less worn condition than that often comprising the main body of the pellet.

I have little to submit as explanation for fur and feathers of horned owl prey at times coming through digestive processes largely clean and unchanged in appearance (Plate 18-B, C; Plate 19-C) or in other instances being reduced to a common consistency of dirty paste. Pellets differing so distinctly may be found in the stomachs of killed owls; may be found in collections from the same owls, free or cap-

tive; and may be produced with captive birds on the same diet.

TYPES OF FOOD HABITS STUDY

Readers interested in a discussion of techniques of raptor food habits study may be referred to Errington, 1932a. For purposes of research on the food habits of the great horned owl, the only methods found to be of much utility were: (1) recording of horned owl prey items found in the field or about nests, (2) stomach analyses, and (3) pellet analyses.

Data from the first method are not likely to be of value in quantitative studies, as small prey is apt to be eaten in such a way as to leave little if any recognizable trace, and the evidence from kills of comparatively large species, especially of large birds, is as a rule overly conspicuous. The method has limited usefulness at times when it may be important to learn whether certain prey species are being taken at all in a given locality.

Analysis of stomach contents has been used by the U. S. Biological Survey in investigations of food habits of birds of prey, including owls (Fisher, 1893), but it is much more adapted to general sampling than to studies demanding mass data from local areas. Obviously, to ascertain the relation of food habits of horned owls to biotic changes in areas of only a few square miles, it is desirable to know more about the current diets of the owls than could be learned from the small numbers of stomachs obtainable at any one time.

Primary reliance has therefore been placed upon the examination of pellets, which are often available by hundreds on areas where the most strenuous efforts would be required to secure any stomachs and which may be collected with trifling disturbance of existing natural relationships. With proper precautions, collections of horned owl pellets may usually (not always, unfortunately) be made with slight likelihood of contamination by pellets from other owls. Sometimes, pellets may be acquired in series revealing food trends of given owl families for many consecutive months, especially when summer studies may be prolonged by "tethering" of the young (Errington, 1932a).

The reliability of pellet analyses for the study of the food habits of the great horned owl may be partially inferred from the discussion presented so far. There is no real distinction between pellets and stomach contents in advanced stages of digestion, as many stomach contents are only pellets not yet disgorged. It is true that prey items not resistant to digestion might be recognized in fresh stomach material and not in pellets, but, in practice some resistant parts of almost any animal likely to be eaten as prey may be fairly well identified in the pellets (Errington, 1930; 1932a).

In view of the frequently worn state of feathers, if not fur, the main reliance in pellet studies has been placed on bone determinations. Feathers and fur may often be valuable, nevertheless, in the identification of many species, notably in pellets containing fragmentary skeletons of confusingly similar forms.

As concerns bones in horned owl pellets, some loss of delicate osseous structures may be expected. Skeletons of the smaller shrews and mice—even of adults—may be represented chiefly by

skulls and the bodies of small birds by mouth parts, the heavier sternal and synsacral fragments, and feet. If the small-sized animals eaten are also immature, the difficulties of making reasonably correct determinations from pellets are accentuated; but, even so, much can be done with immature mateial provided that it comes from areas where the vertebrate fauna is familiar and circumscribed enough to give one some idea of probabilities of occurrence both on the hunting grounds and in the diets of the owls.

It has been experimentally demonstrated (Errington, 1932a) that tarsometatarsi of a bob-white chick as small as 13 grams (about 10 days old) could come through in a horned owl pellet ejected 14 hours after feeding (Plate 20-A). Tarsometatarsi of chicks 15 and 20 grams in weight were easily located in a pellet ejected after 19 hours (Plate 20-B, C). Plate 20 also shows the appearance of bones of young bobwhites of 61 grams (D) and 90 grams (E) sorted out of pellets of mixed composition.

In our Iowa and Wisconsin studies, we have found pellets in dry, loose condition preferable for examination. Pellets may be so hard and brittle that they need to be softened by moisture before tearing apart, but most of them may be readily spread over a piece of paper for preliminary sorting out of skulls, feet, joints, and miscellaneous fragments of diagnostic importance. A reference collection of skins and skeletons of local prey animals is an almost indispensable aid but many items may be recognized at a glance. With experience, the characteristics of certain animal groups may be learned well enough to permit short-cuts even when verification by means of a reference collection may be necessary. Determination of a prey item to the genus is often the best one can do with remains of passerine birds and other small or closely similar animals, and, in some instances, the tracing of an item to the order is a triumph; these difficulties are not peculiar to pellet analyses, however, and under ordinarily satisfactory working conditions it is possible, with care, to make determinations as accurately as the problem may call for.

GATHERING AND PREPARATION OF PELLET MATERIAL

We have found it most profitable to look for horned owl pellets on the ground beneath roost trees in nesting and wintering territories. As the wintering territory of a pair of the owls may frequently be about the same as, or very near, the nesting territory (Errington, 1932c), searches within a few hundred yards of a nest may disclose pellet accumulations not only from spring but also from winter and fall. Early spring, after the snow has melted, has been generally the best time to gather pellets deposited during the cold weather months. Current pellets may be picked up in the nesting territory until the young are ready to leave the nests; then, if juveniles are tethered on the ground with chains and leather anklets before they are able to fly (Errington, 1932a), they may yield pellets as long as attended by adults or as late in the summer as July or August. It has been most difficult to obtain food habits data for late summer and early fall, except when birds were naturally restricted to small islands or isolated

Pla
A.
B.
C.
D.
broke

Plate 17—Horned owl pellet material illustrating manner of feeding.

A. Main pellet mass made up chiefly of fur and long bones of *Peromyscus*.

B. Bones of head and forequarters of bob-white sorted out of the pellet debris (A).

C. Mandibles of 11 *Peromyscus* from the pellet (A).

D. Typical appearance of cottontail bones from horned owl pellets. Note especially the broken leg bones.

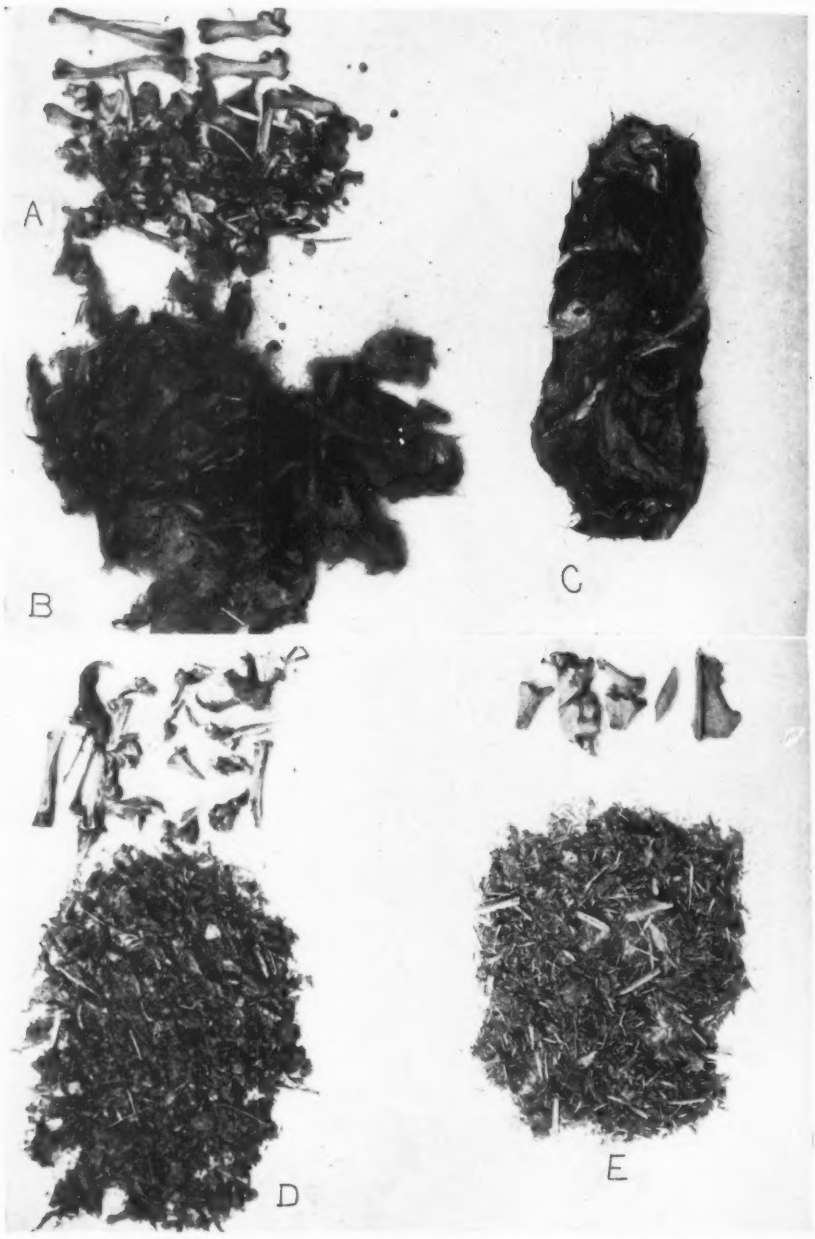

Plate 18—Horned owl pellet material illustrating appearance of different types of prey remains.

A. Bones of immature muskrat separated from pellet mass (B).

B. Largely fur of immature muskrat.

C. Unbroken pellet made up of bones and fur of an adult muskrat. The bones of much of the skull are partially exposed to view.

D. Remains of screech owl showing bones in recognizable condition but feathers badly reduced.

E. Remains of forequarters of ring-necked pheasant, with identifiable and larger bone fragments separated from reduced feather mass.

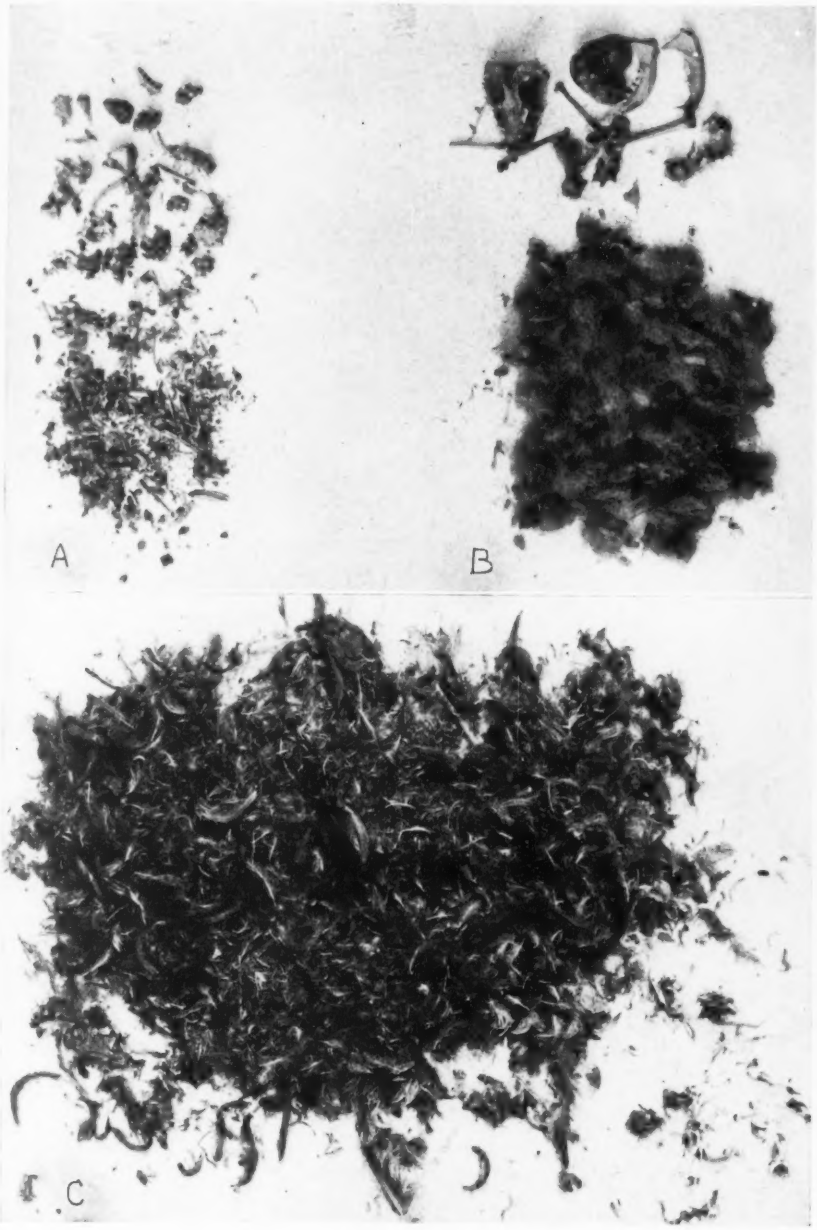

Plate 19—Horned owl pellet material further illustrating extremes in appearance of prey items.

A. Bob-white bone fragments mixed with gizzard contents and miscellaneous debris.
B. Well-preserved remains of forequarters of weasel.
C. Well-preserved feather remains of coot.

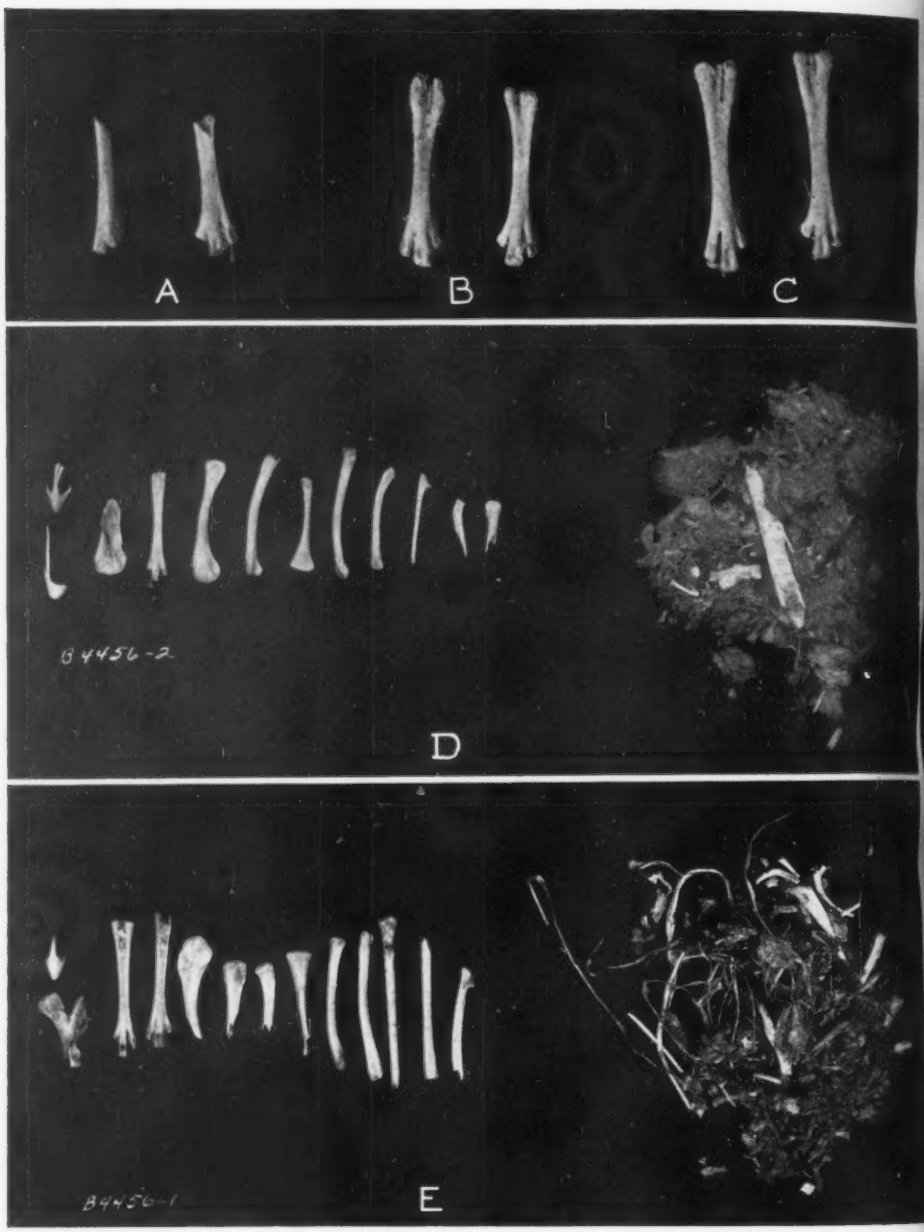

Plate 20—Bone remains of immature bob-whites fed experimentally to captive horned owls and recovered from pellets of mixed composition.

A. Tarso-metatarsi of 13 gram chick.
B. Tarso-metatarsi of 15 gram chick.
C. Tarso-metartarsi of 20 gram chick.
D. Bones at left from young of 61 grams.
E. Bones at left from young of 90 grams.

clumps or fringes of trees for roosting sites.

On the whole, the facility with which horned owl pellet collections may be made varies with the regularity of the living routine of the owls and inversely with the concealment cover available to them. In summer, leafy cover is so abundant in deciduous woods that the owls may find suitable hiding places almost anywhere, and the same is true throughout most of the year in forests that are largely evergreen. When a superfluity of cover is thus available, the principal places where pellets may be found will be in the vicinity of stationary young, either in nests or tethered on the ground.

Spattered feces may or may not be associated with pellets; those of owls are usually less liquid than those of hawks and crows, and may have conspicuous lines and coils of fur and feather debris running through them. Under horned owl roosts, some fecal passages may be thick blobs of greyish material, or the waste "whitewash" may have been perceptibly semi-solid at the moment of impact. Relatively few, large, and perhaps broken pellets made up of rabbit fur and heavy bone fragments may serve to identify roosts as those of horned owls, although the possibilities of other owls using the retreats must be considered.

Barred owls (*Strix varia*) may at times use the same roost trees as horned owls during the same winter, and the problem of differentiating between pellets of the two species may be a serious one (Errington, 1932a; Errington and McDonald, 1937). Horned owls and barred owls, however, tend to occupy different parts of a given range, and one of the best precautions an investigator can take against gathering pellet lots of mixed or doubtful origin is to familiarize himself with the habits of the owls resident in areas under observation. If known retreats are carefully approached, the owls themselves may often be seen and identified,[3] and there may be hooting, shed feathers, prey killed or eaten in a typical manner, and similarly useful "sign." When diets of both owls run strongly to mice, moles, shrews, small to medium-sized birds, lower vertebrates, large insects, crayfish, etc., the presence or absence of broken heavy bones of large prey as adult rabbits in pellets of different ages may give some indication of the species frequenting a particular roost. The safest policy is to discard questionable pellet lots, or at least to record with the data any uncertainties of origin, so that rejection will remain an open question until all doubts are resolved.

Horned owl pellets are rarely found in quantity in any one place—commonly one or two to a half dozen beneath a roost tree. In otherwise shelterless deciduous winter woods, trees with broken or vine-entangled tops furnish protection against discovery and ha-

[3] The horned owl is by no means easily distinguished from other owls if but a fleeting view is obtained in poor light. It is much stockier in build than the barred owl, but the fluffy feathers of the latter make that species appear nearly as large in outline. On the wing a horned owl may give an observer an impression of power and speed lacking in the less compact barred owl. Horned owls commonly breeding in north-central states (Swenk, 1937) are darker than the gray or yellowish barred owls. Long-eared owls (*Asio wilsonianus*) are so much smaller than horned owls that their "horns" should not confuse anyone who has seen both species.

rassment by crows (*Corvus brachyrhynchos*), and under these trees one may expect to find feces and pellets. Holes in rock faces, the larger trees in a woodlot, and occasional conifers scattered among hardwood stands are also acceptable retreats for owls. Horned owl pellets may be found now and then on the ground near the site of eating of large prey, as owls frequently eject the pellet from a previous meal just before eating another—sometimes a pellet evidently from the same carcass.

If several pellets have been broken and their fragments mixed—as after a drop of many yards upon rocks, ice, or sharply sloping ground from a high roost tree—some of them may be pieced together on the basis of size, age, fitting of broken ends, composition, or distinctive coloration. Pellet masses too intermixed to allow separation into individual pellets may be gathered in bulk, but bulk material usually gives inferior quantitative data.

Individual pellets may be wrapped in pieces of paper and dried in preparation for storage until the time of examination. It has been found convenient to keep the dry pellets in flat glassine bags of the kinds obtainable at confectioners and druggists. These bags if kept closed and out of reach of gnawing or chewing animals give the fur and feather contituents of the pellets protection from moths and dermestids and, if necessary, may be readily opened for the insertion of insecticides.

SUGGESTIONS FOR HORNED OWL STUDIES IN CONNECTION WITH WORK ON ANIMAL POPULATIONS

It should be plain that intelligent wildlife management demands a clearer understanding both of predation and of population phenomena than we have at present and that there are here vast fields for significant research (Errington, 1935b). The great horned owl comes as close to being a "key predator" as any of many predator species we have studied in the north-central states, and its food habits through examination of its pellets may often be investigated with comparatively little trouble.

In fact, I believe that a large number of persons engaged in population or life history studies could profitably make the handling of horned owl pellets a routine part of their activities, to be carried on year after year in the same areas as those devoted to the primary investigations. This would not necessarily require complete analysis of the pellet material in the event that such study would be neither feasible nor possible; but students of particular prey species may find it advantageous to look through the available pellet series for representations of the animals in which they may be interested and with the osteology of which they may already be familiar.

Reference collections of prey species suitable for limited purposes may usually be prepared with a reasonable expenditure of time and effort. Skins stretched and dried flat are preferable for comparisons to conventional museum skins, although they do not wear so well. In addition to cleaned skeletons, it is desirable to have in the reference collection bones that have been subjected to horned owl digestive action, and these may be secured through the feeding of captive owls with specific prey or perhaps may be picked out of certain field-gathered pellets contain-

ing only single carefully determined items. It may also be desirable to have reference specimens illustrating sex or age differences for given species and —even when the primary studies may be chiefly monotypic in scope—for species of similar types.

The distribution of the horned owl throughout the wooded and semi-wooded portions of its geographic range makes study possible over much of temperate North America. At one extreme, it may live in country so treeless that it frequents buck brush (*Symphoricarpos*) patches or barren gulches; at another, it may occur in parks and wooded residential districts of large cities. Preferred habitats, however, are woodlots of large size, timber-grown river bottomlands, backwoods, and wilderness.

In common with practically all birds of prey, the horned owl suffers sporadic persecution by man; it is also made the object of concerted compaigning on the part of farmers, hunters, game wardens, and the keepers of shooting preserves, game refuges, and game farms, and in some of the eastern states the gauntlet of guns and traps seems to keep populations thinned down to very low levels. Attractive vacancies in habitable horned owl environment in agricultural Iowa and southern Wisconsin tend to become sufficiently filled by drifting birds so we have had little difficulty finding populations with which to work, but again and again we have had interesting studies abruptly terminated by owl shooters or meddlers.

Whether horned owl studies should be conducted with secrecy or with knowledge of the community or according to some flexible intermediate policy should depend mostly upon circumstances, but, in localities where human interference is apt to jeopardize important research, programs of study should obviously be planned with care —perhaps restricted to areas over which the investigator or cooperating persons may have some control.

Indeed, workers on institutional lands, as refuges, may have singular opportunities for, as well as need of, investigations of horned owl food habits; and, even when the official practice may be to keep the horned owls reduced in numbers, certain areas might conveniently be reserved as sanctuaries for the species. Intraspecific intolerance of the horned owls during the breeding season would rarely permit the occupancy of a sanctuary a square mile in size by more than one or two nesting pairs. This might not result in appreciably more horned owls in the neighborhood than would be there in spite of reduction efforts, but the population would probably consist more of truly resident individuals. Except in the vicinity of game breeding or poultry raising establishments, etc., the resident pair or two of horned owls and the occasional transients that might gain increased protection from possibly a square mile of sanctuary should not be of any great detriment to human interests. The net effects of the so-called destructive habits of horned owls under natural conditions appear to have been much exaggerated, anyway, in both public literature and thought.

In concluding this paper, I would caution prospective investigators against attacks by adult horned owls defending their young. While the majority of horned owls in settled communities

may not come near when their young are being visited, certain individuals may be positively *dangerous* to a lone person carelessly climbing nest trees or picking up pellets about a tethered juvenile. Aside from the risk of infection from talon wounds, an attack may rip open neck or face in a violent manner (Forbush, 1927; Bird, 1929; Errington, 1932 a and c), and the impact may be sudden and strong enough to knock an unwary climber out of a tree. The conspicuous presence of a second person has always been, in our experience, an effective safeguard against actual attacks.

LITERATURE CITED

BIRD, RALPH D.
1929. The great horned owl in Manitoba. Canadian Field-Naturalist, 43: 79–83.

ERRINGTON, PAUL L.
1930. The pellet analysis method of raptor food habits study. Condor, 32: 292–296.
1932a. Technique of raptor food habits study. Condor, 34: 75–86.
1932b. Food habits of southern Wisconsin raptors—Part I. Owls. Condor, 34: 176–186.
1932c. Studies on the behavior of the great horned owl. Wilson Bulletin, 44: 212–220.
1935a. Wintering of field-living Norway rats in south-central Wisconsin. Ecology, 16: 122–123.
1935b. The significance of food habits research in wildlife management. Science, N.S., 81: 378–379.
1935c. Over-populations and predation: a research field of singular promise. Condor, 37: 230–232.
1936. The winter of 1934–35 and Iowa bob-whites. American Midland Naturalist, 17: 554–568.
1937a. Food habits of Iowa red foxes during a drought summer. Ecology, 18: 53–61.
1937b. Winter carrying capacity of marginal ruffed grouse environment in north-central United States. Canadian Field-Naturalist, 51: 31–34.
1937c. What is the meaning of predation? Annual Report Smithsonian Institution, 1936: 243–252.

ERRINGTON, PAUL L., and HAMERSTROM, F. N., JR.
1936. The northern bob-white's winter territory. Research Bulletin 201, Iowa Agr. Expt. Station: 301–443.

ERRINGTON, PAUL L., and MCDONALD, MALCOLM
1937. Conclusions as to the food habits of the barred owl in Iowa. Iowa Bird Life, 7: 47–49.

FISHER, A. K.
1893. Hawks and owls of the United States in their relation to agriculture. U. S. Dept. Agr., Division of Ornithology and Mammalogy, Bul. 3.

FORBUSH, E. H.
1927. Birds of Massachusetts and other New England States. Massachusetts Dept. of Agriculture, 2: 1+461.

GAUSE, G. F.
1934. The struggle for existence. Williams and Wilkins, Baltimore, Md.

KING, RALPH T.
1937. Ruffed grouse management. Jour. Forestry, 35: 523–532.

MCATEE, W. L.
1932. Effectiveness in nature of the so-called protective adaptations in the animal kingdom, chiefly as illustrated by the food habits of Nearctic birds. Smithsonian Misc. Coll., 85(7) (Publ. 3125).

REED, BESSIE P.
1925. Growth, development and reactions of young great horned owls. Auk, 42: 14–31.

REED, C. J. and REED, B. P.
1928. The mechanism of pellet formation in the great horned owl (*Bubo virginianus*). Science, N.S., 68: 359–360.

SUMNER, E. LOWELL, JR.
1933. The growth of some young raptorial birds. University of California Publications in Zoology, 40: 277–308.

SWENK, MYRON H.
1937. A study of the distribution and migration of the great horned owls in the Missouri Valley region. Nebraska Bird Review, 5: 79–105.

EXPLANATION OF PLATES

Plate 17—Horned owl pellet material illustrating manner of feeding.

A. Main pellet mass made up chiefly of fur and long bones of *Peromyscus*.

B. Bones of head and forequarters of bob-white sorted out of the pellet debris (A).

C. Mandibles of 11 *Peromyscus* from the pellet (A).

D. Typical appearance of cottontail bones from horned owl pellets. Note especially the broken leg bones.

Plate 18—Horned owl pellet material illustrating appearance of different types of prey remains.

A. Bones of immature muskrat separated from pellet mass (B).

B. Largely fur of immature muskrat.

C. Unbroken pellet made up of bones and fur of an adult muskrat. The bones of much of the skull are partially exposed to view.

D. Remains of screech owl showing bones in recognizable condition but feathers badly reduced.

E. Remains of forequarters of ring-necked pheasant, with identifiable and larger bone fragments separated from reduced feather mass.

Plate 19—Horned owl pellet material further illustrating extremes in appearance of prey items.

A. Bob-white bone fragments mixed with gizzard contents and miscellaneous debris.

B. Well-preserved remains of forequarters of weasel.

C. Well-preserved feather remains of coot.

Plate 20—Bone remains of immature bob-whites fed experimentally to captive horned owls and recovered from pellets of mixed composition.

A. Tarso-metatarsi of 13 gram chick.

B. Tarso-metatarsi of 15 gram chick.

C. Tarso-metatarsi of 20 gram chick.

D. Bones at left from young of 61 grams.

E. Bones at left from young of 90 grams.

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CUTTING OPERATIONS TO IMPROVE WILDLIFE ENVIRONMENT ON FOREST AREAS

James N. Morton and John B. Sedam

On much forest land in Pennsylvania the canopy of trees has closed, thereby making environmental manipulations necessary if the areas involved are to maintain the wildlife populations which they can and should support.

Too well accepted to be disputed is the fact that a dense growth of mature trees, or a stand of growing trees, in which the crown canopy has closed over a considerable area, does not afford conditions favoring an abundance of wildlife. Large timber standing thickly together sheds its limbs for some distance above the ground, leaving no low branches upon which browsing animals may feed. The same shading process which eliminates low limbs also precludes the growth of any appreciable amount of understory.

Consequently, a stand of large, even-aged, and in some instances uneven-aged trees, often has an open floor, carpeted only with fallen leaves or pine needles, and offering scarcely any food or cover. Such conditions reduce ground-dwelling wildlife to a minimum, and provide optimum habitat only for animals which require the environment of leafy canopies.

The forest district in Pennsylvania, which at this time presents the greatest problem as to wildlife habitat, lies in the central and northern parts of the State and in both the Allegheny and Appalachian mountain systems. Here is range, that is, or has been, favorable for the white-tailed deer, snowshoe hare, and ruffed grouse, as well as the black bear, cottontail rabbit, raccoon, and in certain sections, the wild turkey.

These lands are owned and controlled by both private individuals and public agencies, which include the U. S. Forest Service, Pennsylvania Department of Forests and Waters, and the Pennsylvania Game Commission.

On the lands controlled by the Commission, work was undertaken to provide better habitat for wildlife. That part of the work having reference to cuttings is here considered. Planting is mentioned only as it may refer to a few trials in cut-over plots.

During the spring of 1936 the Commission authorized an extended program of game food and cover development on the lands under its direct control. These lands, known as State Game Lands, total 573,458 acres, and are distributed in 53 of the State's 67 counties.

An outline for development was immediately prepared and put into effect as rapidly as possible. It seemed important to give careful and urgent consideration to cutting operations to make the lands of most value to wildlife, and at the same time to give due recognition to timber production. Much of the work has been experimental. Programs and procedures had to be changed from time to time, but because of the urgency of the problem the work was conducted on a fairly large scale. Deer were starving and snowshoe hares and grouse had lost much of their previous range.

The cuttings undertaken were principally of four kinds, namely, release cuttings, slashings, thinnings, and felling timber for sale.

RELEASE CUTTINGS

Release cuttings were carried on about grapevines, wild apple, hawthorns, black berries, mountain ash, dogwood, beech, huckleberries, sumacs, and many other game food producing trees, shrubs, and vines. These cuttings were designed to remove all competitive growth and to permit sunlight to enter and stimulate the game food plants and increase their fruiting capacity.

The size of the release plots varied from a fraction of an acre to several acres, depending upon the needs of game and on local conditions. In a number of instances several acres of blackberries were released in good grouse and black bear territories. Release plots in most instances, however, were confined to areas of not more than one-fourth to one-half acre. Plots were scattered, about a quarter of a mile apart, wherever there was suitable material for releasing. So far as possible, the plots were confined to the so-called waste land types, such as shallow soils, ledges of rock, and marshy or swampy areas.

Every effort was made by the local manager of the land to find all openings resulting from past timbering operations. In many of these, including old roads, tram grades, mill sets, camp sites, and abandoned clearings, being reclaimed by tree growth, steps were taken to preserve open areas and release game food producing trees, shrubs, and vines. This was accomplished by felling and piling the scattered trees that were taking possession of the openings.

In release cutting, special attention was given to apple trees, one of the best sources of game food. A great many are found growing wild around abandoned lumber camps, and along old tram grades and wagon roads. Thousands were released from competitive growth and pruned.

The work of the first year resulted in a greatly increased crop of fruit on practically all trees which were treated. Many that had not borne fruit for years, because of suppression and lack of pruning, produced a fairly good crop. Deer and rabbits browsed heavily on the pruned branches which were piled for their benefit.

When grapevine releasing was started, trees which had vines high up in the branches were felled with the tops of two or more together, to get the vines nearer the ground, make the fruit more available, and at the same time open up the area to provide the vines with more sunlight. It was found that deer, especially where abundant, began browsing on the tender foliage of the vines and in some cases practically destroyed them. To overcome this difficulty, where greatest, several trees in close proximity to those on which the vines grew were cut partially through about 4 feet above ground. These trees were felled across each other and remained attached to the stumps. The trees on which the vines were growing were then cut entirely through about one foot above ground and felled onto the partially cut trees which provided a natural support over which the vines

matted to form a dense cover valuable to wildlife and were at the same time beyond the reach of the deer.

SLASHINGS IN PLOTS

In areas where cover and food conditions were unsatisfactory and where the timber was not large enough to market, a great many strips or plots were cut to stimulate sprouts, briars, shrubs, and other ground growth. Many different methods of handling this work were tried. On some areas rectangular plots of one-half acre were cut and all brush thrown in large low piles and burned to promote the growth of briars and to furnish dusting places. On other plots part of the brush was piled over stumps and logs as escape cover for wildlife and the remainder burned. In some cases, strips were cut 70 to 90 feet wide and the brush "windrowed" down the center of the strip by felling trees with their tops to the center. The width of strips was twice the height of trees along the edges, sufficient to allow sunlight to reach all parts of the plot for a considerable period each day.

In other slashings the trees were felled with tops all to the center of a more or less circular plot. Where deer were hard pressed for food it was found necessary to fell for browse some trees scattered over the plots. Before this practice was adopted the deer destroyed potential grouse food by consuming all reproduction as fast as it appeared, often leaving an opening bare. The brush remaining from scattered tops protected some vegetation until it got started, thus increasing the ground cover.

On some plots the planting of Japanese rose, Japanese barberry, and buckthorn was carried on to a limited extent. It was thought that conditions for grouse would be improved in this way. It is too early yet to determine whether or not this is good practice.

Much of the work was done by CCC, NYA, and WPA labor which made possible a number of operations which could not otherwise have been attempted. We are convinced, however, that the benefits of slashings to wildlife justify the expenditures.

We believe that the most practical method is to cut in zigzag strips 50 to 90 feet wide, and where possible scallop the sides to provide more edge. The length of slashings can be anywhere from 300 to 600 feet, depending upon local conditions. The trees should be felled in windrows or left scattered over the plot; a few trees may be felled back into the adjoining timber to provide more cover and additional sunlight for shrub production at the edges of the cut strip.

A record of each slashing plot was kept on a form on which was noted the location of the plot, size, slope, kind of growth prior to cutting, in a general way the method used in carrying on the work, man days required for the job, and dated observations on wildlife utilizing the plots.

A total of about 2,500 acres was cut in 700 release and slash areas. Millions of good game food producing plants were given a better opportunity to fruit, thereby contributing in a large measure to available food supplies and providing other essential factors for good wildlife range.

It is proposed to maintain the more desirable plots permanently for wildlife

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A. (*Upper*)—Removal of a portion of the timber stand released plants which provide game food in the form of berries and seeds, in addition to stimulating sprout growth essential as browse for deer and cover for all wildlife.

B. (*Lower*)—The fruiting capacity of game food producing shrubs and vines is greatly increased by the removal of overtopping growth.

by repeating cuttings at intervals of a few years, as needed, to keep them in the most satisfactory condition.

STUMP-HEIGHT EXPERIMENT

In an effort to determine the height of cuts producing the most vigorous sprout growth, experiments were made in four different counties. Trees on these areas consisted of red maple, American beech, yellow birch, and oaks under 6″ d.b.h. These areas were each divided into four quarter-acre sections and trees felled at the following heights: Section 1, 6″ high; 2, 12″ high; 3, 18″ high; and 4, 24″ high.

Due to variations in the work of individuals making the cuts, we were unable to group enough trees cut the required height to make a satisfactory statistical study and graph the results.

Readings taken on several stumps in each section, after one growing year, however, provide the following data: (1) On all plots the greatest average growth was from stumps cut 12″ from the ground, and (2) trees cut 18″ to 24″ high yielded a higher percentage of growth from the stump cambium. Whether this growth will continue to live as the stump dies is problematical.

It is apparent from the observations made that trees felled by cutting the stumps 6″ to 12″ high will yield more vigorous sprout growth than those cut 18″ to 24″ high.

THINNINGS

It is well known that thinnings in forest stands beyond the sapling stage are among the most beneficial cultural operations both for wildlife and for the trees. Early plantation thinnings in England were conducted primarily to improve conditions for game. Trees in stands which are thinned produce larger seed crops, hence more food for wildlife. The openings made by removal of part of the stand admit sunlight which stimulates the growth of sprouts, shrubs, and other vegetation valuable as food and cover for wildlife.

Hundreds of acres of forest thinnings were made on State Game Lands during the past two years. In many cases the thinning was more thorough than would ordinarily be done if timber production alone were considered. Radical thinning also lengthens the period after which it is necessary to repeat the treatment. Cultural operations to be of most value must be continuous. Care was exercised to save valuable fruit- or nut-producing species present in the stands. Where mast-producing species, as oak and beech, were found, thinnings as severe as 50% to 75% were made to give these trees an opportunity to develop a more open type of crown, and increase their fruiting capacity. Ground growth on the liberally thinned stands is greatly increased.

Where large areas were greatly thinned, enough growth was made so that a good percentage of sprouts grew beyond the reach of deer, thus establishing an uneven-aged stand, beneficial to forest wildlife. The ensuing heavy ground growth of herbs and shrubs provided conditions essential for the survival of small game. At least 50% crown removal was necessary to insure the growth of an adequate understory.

Cutting of plots in solid yellow birch stands was followed by no sprout growth whatever, but the surrounding birch trees readily reseeded the areas.

Sugar maple, as a rule, is not a vigorous sprouter. Red maple is probably the best in that respect of all the trees cut. However deer preference kept its growth to a minimum height.

Aspen in most instances restocked thinned areas by suckering from the roots.

All sprout growth and seedlings were more vigorous when protected by felled tree tops.

Heavy browsing of terminals reduced height growth and stimulated growth from side buds, thus resulting in a greater number of branches for browse material.

The field notes submitted by many of the local land managers were of interest and value. These, along with personal observations and studies, verified information useful to the technicians responsible for manipulating game habitats.

In remote sections where slashings or thinnings were conducted, a great increase in the number of snowshoe hares was reported. Evidence such as number of rabbits seen, peeling of sprout growth, droppings, and tracks on treated areas substantiated these reports. Without doubt the fresh cuttings attracted many of these rabbits from surrounding range, but the occurrence emphasizes the need for the renewal of ground cover in second growth stands that have shaded out the understory.

Cottontail rabbits have been observed feeding on treated plots in remote forest areas. In one instance twenty-four rabbits liberated on a recently managed area, which prior to management was practically void of game, bred and restocked the area to such an extent that local hunters were enabled to take a fair kill the following season.

Periodic reports were received of broods of ruffed grouse exercising, dusting, and feeding on areas where forest cuttings had been conducted. Such observations indicated the need of forest openings in optimum grouse environment.

On radically thinned areas practically all men reported that released trees and shrubs yielded more and larger fruit than similar trees in adjoining untreated stands.

White-tailed deer utilized practically every treated area within the forest range, browsing heavily on sprout growth and on tree and shrub reproduction, and grazing the herbaceous growth. In many regions deer were literally kept alive from day to day by slashings. The statement in the report of one field manager, "Deer seem to know the sound of the axes, and follow cuttings as fast as they are made," may seem incredible, but its actuality serves emphatically to show the extent to which the ground growth had been depleted. Herds have been known to bed down on slashed areas and feed there for several days.

In many instances deer had followed through areas where apple trees had been released and pruned, browsing heavily on the discarded twigs. Rabbits remained in the vicinity of apple prunings, which provided food during the entire winter.

The use of the treated areas by forest game is ample proof of the value of the cuttings in managing wildlife habitat in a heavily wooded region. Such value in terms of the production of browse

and game food producing shrubs, is shown in Table I.

TIMBER SALE OPERATIONS

On all areas where cutting was needed and where the timber was of marketable size, every effort was made to arrange for timber sales. During the past two years approximately 40 agreements have been made, calling for lumber, mine props, mine ties, cord wood, pulp wood, chemical wood, material for birch oil distillation, etc., on a total of approximately 8,700 acres. More than $8,000 was received from such sales since the program was authorized less than two years ago.

Agreements entered into with operators included certain definite restrictions, depending upon the area to be cut. In general, material was cut down to a specified diameter limit. This assisted in converting even-aged into uneven-aged stands, of great value for wildlife.

The purchasers agreed to leave all good game food producing species, such as beech, cherry, etc., as specified by the local manager of the land, and sufficient den trees to provide for squirrels and raccoons.

Cutting units were scattered as much as possible in areas from one acre in size up to one hundred acres. A few one and two acre units were cut by purchasers getting cord wood. Where the cutting was for pulp wood, chemical wood, and mine ties the tracts ranged from 25 to 50 acres. Much larger areas were required by purchasers interested in timber of size which necessitated the setting up of a sawmill.

Timber sales are the most satisfactory method of handling the cutting problem. Operation in this way may be made to yield a profit as well as greatly to improve the area for wildlife.

SUMMARY

In order to maintain satisfactory conditions for wildlife on reserved forest areas, it is imperative that cultural operations be carried out. Where the canopy is closed it is necessary to use the axe liberally, both to influence the composition and density of the forest and to favor different kinds of wildlife. It must also be kept in mind that the forest is never static but always changing, hence requires constant attention and follow-up treatments to keep it in condition to foster an abundance of wildlife.

Cuttings can be of different kinds depending upon the nature and size of growth. Where the material is large enough, the cuttings, for the sake of economy, should be for wood sales. The purchaser in each case must be required to enter into an agreement specifying how the work is to be done. Specifications should include among others a provision that game food trees and den trees must be left standing.

Thinning is one of the most valuable cultural operations because it benefits both wildlife and the trees. Good game food producing trees, shrubs, and vines, and some den trees must always be left on treated areas.

Where severe thinning is conducted there is an increased growth of vines, shrubs, and herbaceous ground cover, improving the habitat for all forest game species.

Release cuttings around such game food producing plants as apple, haw-

TABLE
GROWTH ON

(Growth and reproduction studies showing results of cuttings on nineteen different

Site No.	State Game Lands No.	Plot Location	Date of Study	Date of Cutting	Method of Cutting	Principal Material Cut 1"-6" D.B.H.	Method of Brush Disposal
[1]1	33	Centre Co.	2- 9-38	Jan. 1935	Clear cut	Red Maple Chestnut Oak	Lopped to ground
2	12	Bradford Co.	3-17-38	Jan. 1935	95% crown removed	Red Maple Hard Maple Aspen	Lopped to ground
[1]3	33	Centre Co.	2- 8-38	Feb. 1936	25% crown removed	Red Oak Chestnut Oak	Lopped to ground
[1]4	33	Centre Co.	2- 8-38	Feb. 1936	50% crown removed	Red Maple White Oak	Lopped
[1]5	33	Centre Co.	2- 8-38	Feb. 1936	75% crown removed	Chestnut Oak	Lopped
6	12	Bradford Co.	3-17-38	Aug. 1936	Clear cut	Maple species Beech	Piled and some burned
7	75	Lycoming Co.	10-13-37	Sept. 1936	Clear cut	Maple Water Beech	Piled and burned
[1]8	80	Lebanon Co.	3-24-38	Oct. 1936	Clear cut	White Oak Chestnut Oak	Brush piled
9	13	Sullivan Co.	2-18-38	Dec. 1936	80% crown removed	Maple species Yellow Birch	Brush piled to side of plot
10	13	Sullivan Co.	2-17-38	Dec. 1936	Clear cut	Maple species Yellow Birch	Brush piled off plot
11	57	Wyoming Co.	3-16-38	Jan. 1937	Clear cut	Red Maple Fire Cherry	Brush cleared off
12	12	Bradford Co.	3-18-38	Jan. 1937	Clear cut	Fire Cherry	Brush lopped on ground
13	57	Wyoming Co.	2-17-38	Feb. 1937	Clear cut	Aspen Water Beech	Piled off plot
14	13	Sullivan Co.	2-12-38	Feb. 1937	75% crown removed	Red Maple Fire Cherry	Piled off plot
[1]15	33	Centre Co.	9-29-37	Feb. 1937	50% crown removed	White Oak Maple	Piled on plot
16	26	Cambria Co.	3-15-38	Mar. 1937	Clear cut	Maple species Fire Cherry	Piled on plot
17	26	Cambria Co.	3- 8-38	Mar. 1937	Clear cut	Red Maple Sassafras	Piled on plot
18	108	Cambria Co.	3- 9-38	April 1937	98% crown removed	Maple species Ironwood	Windrowed
19	12	Sullivan Co.	3-17-38	June 1937	Clear cut	Maple species Fire Cherry	Windrowed

[1] Where oak species were cut, the stands were dense, necessitating the removal of many mast producers.

1
TREATED AREAS

State Game Land Areas. All growth data based on 1/90 acre sample plot studies.)

Material Released	Sprout Yield per Acre		Count of Reproduction per Acre	Species in the Reproduction
	Sprout Growth	Ave. Height		
	20,520	48.4"	529,290	Hickory, Sassafras, Huckleberry, Panic Grass, Barren Strawberry, Bracken Fern, Star Grass, Teaberry, Mosses
Bush Honeysuckle	13,410	15.1"	(Not counted)	Barren Strawberry, Panic Grass, Star Grass, etc.
Hickory, Red Oak, Dogwood, Juneberry	19,170	13.2"	6,310	Sassafras, Huckleberry, Witch Hazel
White Oak, Chestnut Oak, Juneberry	19,890	19.5"	360,900	Huckleberry, Grasses, Barren Strawberry, Rose, Sassafras
White Oak, Chestnut Oak	20,070	27.8"	367,830	Bracken Fern, Barren Strawberry, Grasses, Sassafras, Teaberry, Huckleberry
	40,680	4.2"	(Not counted)	Grasses, Mosses, Ferns
	36,630	7.5"	110,140	Aspen Seedlings, White Oak Seedlings, Witch Hazel Seedlings, Panic Grass, Blackberry, Mullen, Laurel, Fern, Fire Weed, Violets
Hickory, Wild Crabapple, High Huckleberry	54,720	13.1"	123,390	Partridge Berry, Dwarf Sumac, Panic Grass, Barren Strawberry, Blackberry, Beaked Hazelnut
Beech, Hobblebush	9,180	18.7"	2,970	Blackberry Seedlings
	10,170	17.3"	92,520	Blackberry, Yellow Birch Seedlings
	43,560	7.8"	(No growth on ground)	
	60,030	19.2"	(Not counted)	Mosses, Partridge Berry, Tansy, Mullen, Fern, Grasses
	42,210	30.4"	2,970	Blackberry, Staghorn sumac
Blackberry	66,420	14.3"	(No growth on ground)	
Teaberry, White Oak, Huckleberry, Juneberry, Thornapple, Beaked Hazelnut	29,160	15.0"	263,160	Teaberry, Thornapple, Panic Grass, Sassafras, Huckleberry
	7,110	30.4"	14,760	Blackberry, Witch Hazel, Black Locust
	13,950	24.1"	47,610	Blackberry, Black Locust, Sassafras
Maple Leaf Viburnum, Sugar Maple	61,020	25.2"	7,920	Blackberry, Mapleleaf Viburnum
	19,980	3.5"	270	Blackberry

thorn, wild grape, dogwood, beech, etc., which provide a large part of the fall and winter food of many kinds of wildlife, are relatively simple and inexpensive. The amount of game food is greatly increased by these operations and the results obtained are ordinarily much more satisfactory than attempting to establish game food species by planting.

Slash plots are very desirable in large forest tracts where the tree growth is dense but is not of a size financially profitable to market. Zigzag strips 50 to 90 feet wide are probably the most satisfactory slashings for the benefit of forest game. Ensuing sprout growth and increased reproduction augment food and cover essential for wildlife.

All openings in forest areas, as along old roads and tram grades, and at abandoned camp sites and clearings, should be maintained by removing trees to release shrubs and vines and to insure the open areas so essential to wildlife environment.

If stumps are cut 6–12″ high, apparently more vigorous sprout growth for a longer time can be expected than when the trees are cut higher.

When plot slashings are conducted where deer are abundant, it is imperative that scattered tops be left on the ground to attract the animals and thus protect from browsing the reproduction that is of such great potential value as food and cover for other forms of forest wildlife.

On treated forest areas, the carrying capacity for such game as grouse, snowshoe hares, and deer is considerably increased by the improved food and cover conditions.

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BEAVER FOOD UTILIZATION STUDIES

Shaler E. Aldous

The quest for beaver fur in the northern part of the United States and Canada was largely responsible for the early exploration of this territory. Today the beaver populations are much reduced, not only because of past trapping activities but also because of restriction by lumbering and farming operations of areas where the animals can maintain themselves. This north country still contains millions of acres, however, that are suitable for beaver habitation, and under present trapping laws and closed seasons the animals are gradually increasing.

As to the future, it is not unreasonable to visualize the beaver as one of the most valuable natural resources of the region. Good management will be needed to maintain this resource on a permanent basis. Two of the things we need to know to make a success of management are how many beaver can be supported on the food and water available and how we can manage these resources so that they will meet the needs of the animals.

In order to improve the basis for management, the writer in the fall of 1936 began a study of beavers in relation to the forest with the view of finding answers to the following questions:

1. What is the relative importance of the various food species and their size classes to the beaver?

2. What percentage of the trees cut by beavers are utilized and what proportion of the food available from them is actually consumed?

3. Considered as a standard ration how much of the best food do beaver require daily?

From the findings of such studies, it seemed that methods of estimating carrying capacity of beaver sites now occupied and of potential sites could be determined and that anyone contemplating beaver farming involving the artificial feeding of beavers could appraise available food in terms of beaver years.

The study was begun by having a group of CCC enrollees at the Superior Branch of the Lake States Forest Experiment Station, Ely, Minnesota, peel the bark and cut the twigs from a series of 74 aspens, 1–7 inches in diameter. The bark of each tree and its divisions down to branches ½ inch in diameter was peeled and weighed. The twigs less than ½ inch in thickness were then cut off and weighed separately and this amount added to the bark weight gave the total beaver food available. Use of the ½ inch diameter criterion in segregating twigs and bark was justified by observations that under normal conditions beavers will eat entire most twigs up to ½ inch in thickness. The figures obtained from these peeling experiments were worked up under two classifications: (1) inch classes based on outside stump diameter, and (2) those based on diameter breast high (d.b.h.). It seemed that both sets of figures might be needed to meet the varied requirements of foresters, wildlife managers, and research men. All timber cruising is done on a d.b.h.

basis and the forester needs this scale for interpretation. The wildlife manager and research man will often be working at occupied dams where stumps only are left, and the stump-diameter scale must be used.

Field studies had indicated that the greatest waste by beavers was in the larger diameter classes, where only the tops were utilized. A series of these trees, therefore, was cut and only the branches and the tops down to 3, 4, 5, and 6 inch diameters were peeled so that the waste factor could be determined. The proportion of twigs to bark of the upper trunk and branches of these larger trees was determined and that figure applied to trees of smaller diameters when the bark of the lower trunk was not utilized.

These latter figures will be of little use to the forester or wildlife manager; they are primarily for the research worker who is attempting to establish a utilization factor for colleagues in appraisal and management work.

Figure 1 shows curves by which the size classes of aspen can be appraised in ounces of available food. Ounces rather than pounds are used for greater accuracy. Figure 2 is the curve for determining according to diameter at the upper cut the food available from the tops of trees when the bark of the lower trunk is not eaten.

The next step in the study was to determine actual utilization and waste in relation to the available supply of aspen at occupied beaver ponds. In the fall of 1936 the cut stumps and logs around five beaver dams were spotted with a durable red paint so that when the survey in the fall of 1937 came to be made, only trees cut in the elapsed year would be measured. At each of these 5 sites every tree cut by beavers in that period was measured at the stump and note made of its utilization. Degrees of utilization were recorded as, completely used, partially used, and completely wasted. For the trees of the middle category a measurement was recorded of the diameter of the top where it was cut. With these figures it was possible to apply the curves of Figures 1 and 2 and estimate the quantity of food available from the trees that had been cut and also to determine the amount actually utilized. Table 1 gives the degrees of utilization of aspen and birch at these five dams. The term utilization is here used in a broad sense. Any trees or their parts removed from the immediate vicinity of cutting, regardless of ultimate disposition, were considered utilized. The material may have been eaten, used in dam or house construction, or lost in transport.

Applying the curves in Figures 1 and

TABLE 1

THE DEGREE OF UTILIZATION OF ASPEN AND BIRCH CUT BY BEAVERS AT FIVE DAMS IN THE SUPERIOR NATIONAL FOREST, FALL 1937

Species	Number of trees cut	Completely used		Partially used		Completely wasted	
		Number	Per cent	Number	Per cent	Number	Per cent
Aspen	456	122	27	200	44	134	29
White birch	32	5	16	20	62	7	22

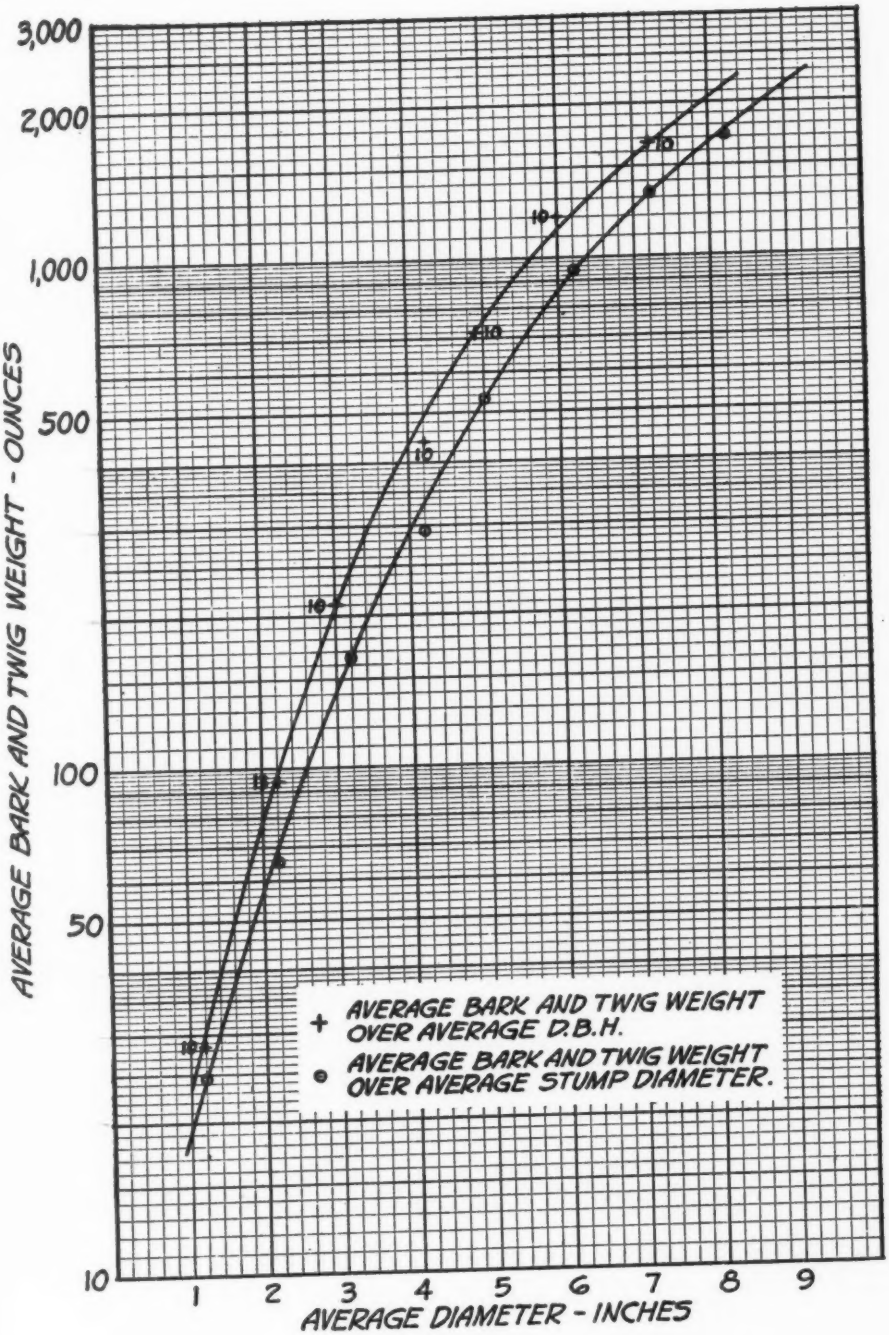


Fig. 1. Curves for computing the weight of bark and twigs from aspen trees of various diameters.

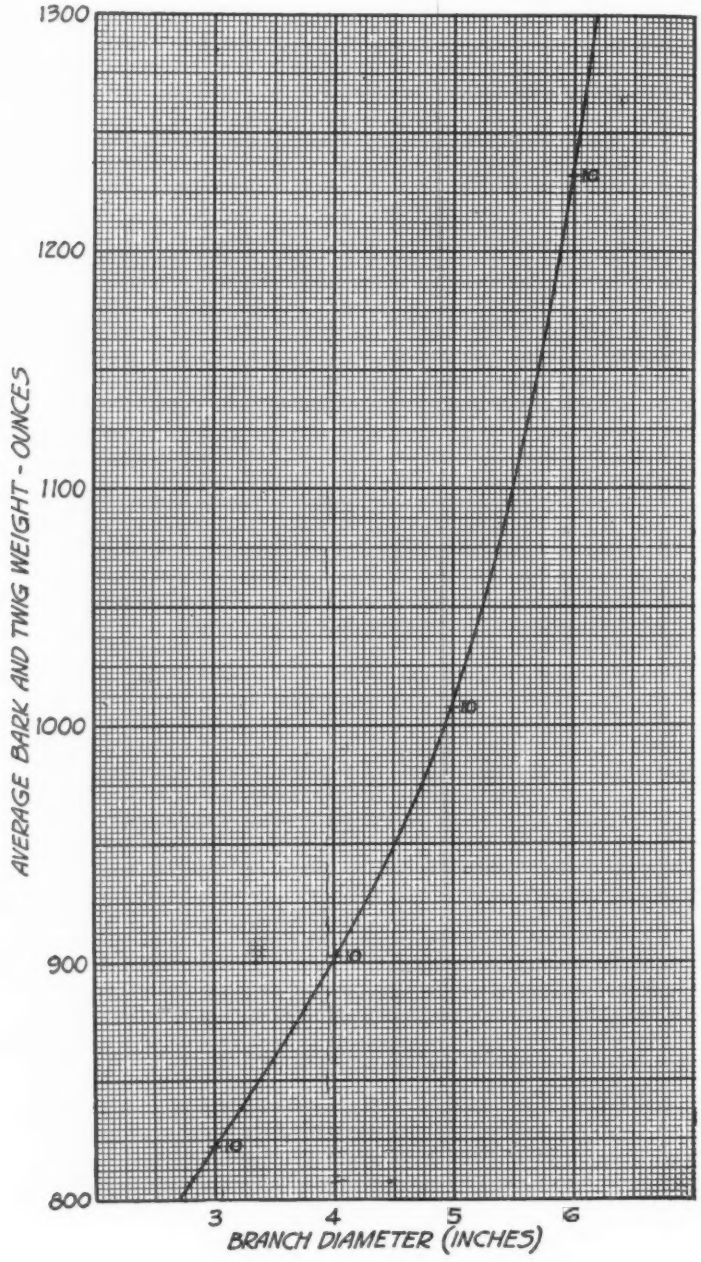


Fig. 2. Curve for computing the weight of bark and twigs from the tops of aspen trees according to the diameter at the upper cut when the bark of the lower trunk is not eaten.

2 to the 456 aspens cut at these five dams, it is estimated that they comprised a potential total of 19,420 pounds of food of which only 6,987 pounds or 36% was actually utilized. Bailey (1) estimated a 50% wastage by beavers at times but the present figures show that about 64% by weight was wasted. The greater part of the trees that were completely wasted were

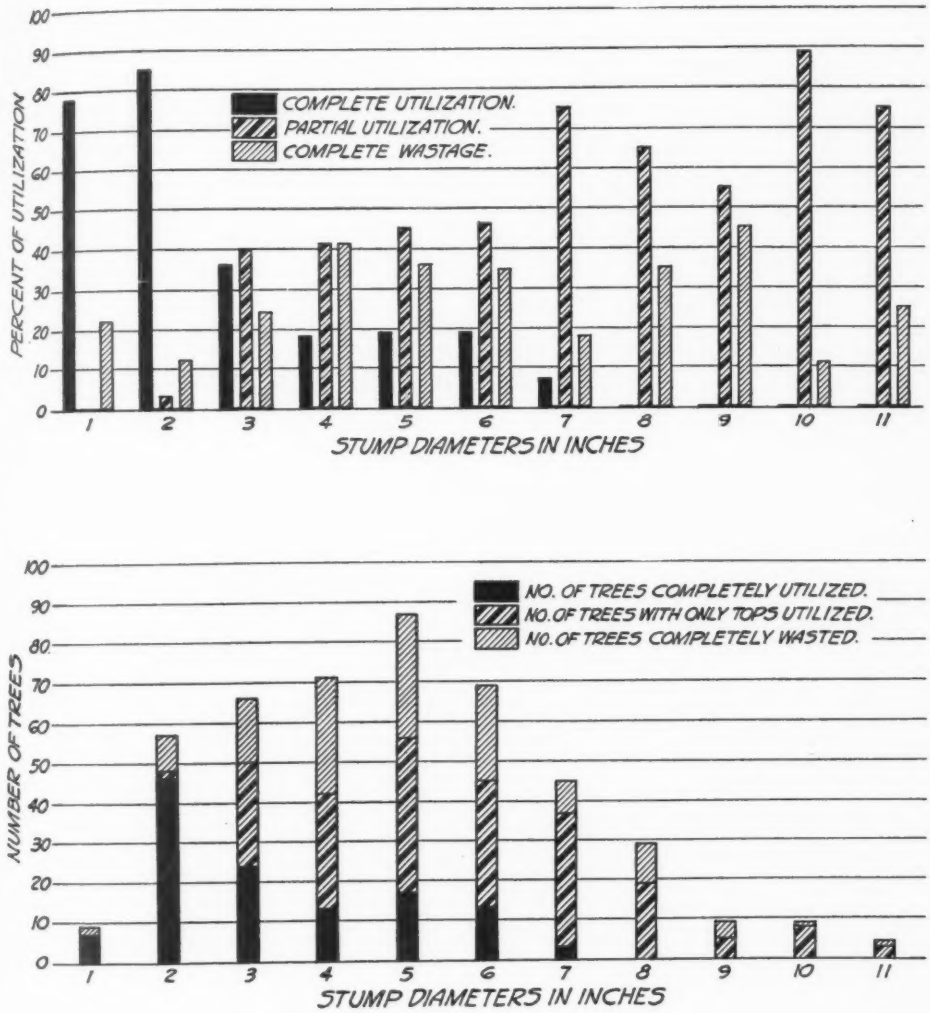


Fig. 3. The utilization of aspen by beavers.

A (*lower*). The bars represent the total number of trees in each diameter class that were cut by the beavers at five dams.

B (*upper*). The bars represent the percentage of trees variously utilized in the different diameter classes.

those lodged in falling after being cut. Other trees in dense timber and rock ledges are the usual obstacles keeping cut trees from falling within reach of the animals.

The bar-graphs (Figs. 3-A and 3-B) show the number of trees and the percentage of utilization in each stump diameter class of the 456 aspen trees that were cut at the dams studied. It will be noted that the greatest proportion of complete wastage was in trees 4 to 6 inches in diameter; beyond 9 inches there was seldom complete wastage. This is due to the failure of the lighter trees to crash through surrounding growth as do the larger ones, and the resultant high frequency of lodging.

The greatest total wastage, however, was not in lodged trees but in those of which only the tops were utilized (Pl. 22). This wastage occurs mostly in the larger trees and its degree seemed to be governed mainly by distance from the water and lay of the land.

There was a decided trend toward a greater percentage of total utilization of the available food in the 1, 2, and 3 inch stump diameter classes, but the quantity produced was small in comparison with that obtainable from the larger trees even though the latter were only partially used. For example: a 7 inch tree, 50% utilized, will provide approximately the same quantity of food as four 3 inch trees completely utilized. Because the beavers prefer the small twigs, and the bark of branches to that of the trunk, and because the ratio of top to trunk is greater in the larger diameter classes, there is more choice food available even though there is also a greater actual waste. The larger trees were used for the most part only after the smaller ones were gone, and in most cases were cut at dams that have been in existence for several years.

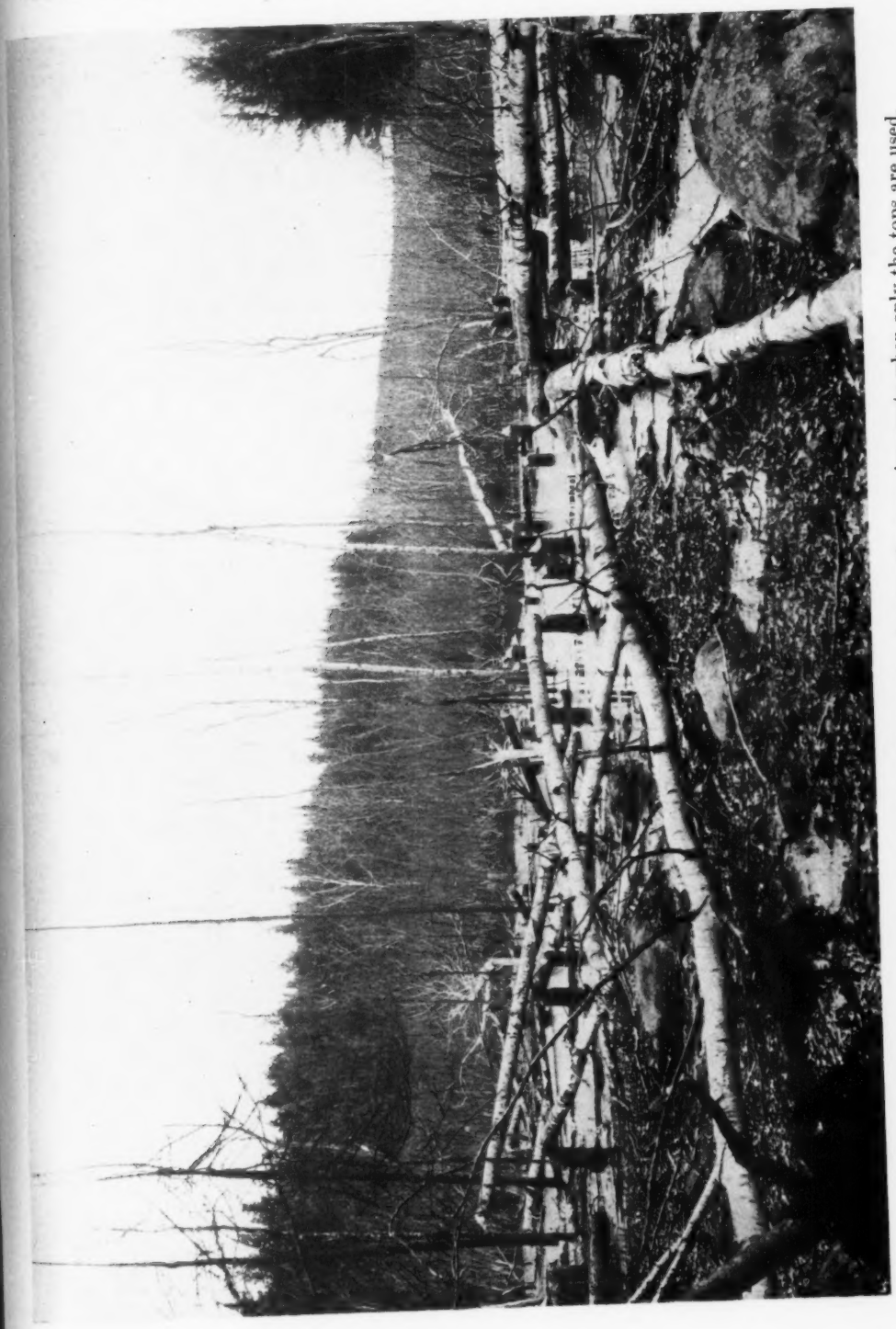
TABLE 2

UTILIZATION OF ASPEN CUT BY BEAVERS AT FIVE ACTIVE DAMS

Stump diameter	Number of trees	Pounds of food available	Pounds of food utilized	Per cent of utilization	Per cent of waste
(inches)					
1	9	19	15	80	20
2	57	276	244	88	12
3	66	730	367	50	50
4	72	1,474	530	36	64
5	87	3,020	1,119	37	63
6	69	4,080	1,407	35	65
7	45	3,943	1,362	34	66
8	29	3,238	970	30	70
9	9	1,080	280	26	74
10	9	1,080	495	46	54
11	4	480	198	41	59
Totals	456	19,420	6,987	36	64

Data on degree of utilization are summarized in Table 2, from which the degrees of utilization in the various size classes can be compared with each other and with the total.

An attempt was made at the beginning of the study to measure and mark all species of shrubs eaten by beaver. It was soon learned, however, that the



Felled aspens at a beaver dam in northeastern Minnesota, showing the excessive waste when only the tops are used.

UNIV. OF MICH.

AVERAGE BARK AND TWIG WEIGHT - OUNCES

J

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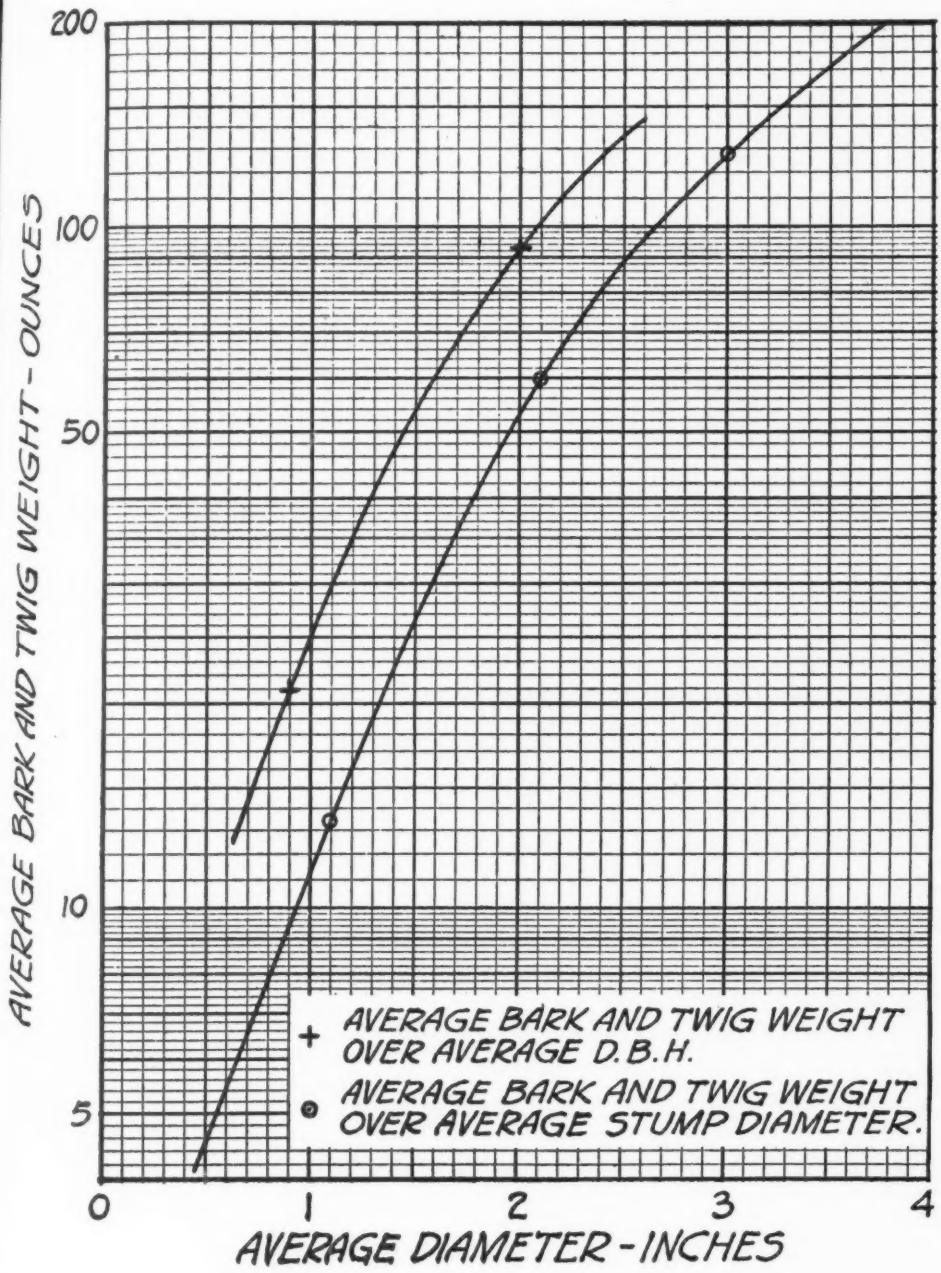

Fig. 4. Curves for computing the weight of bark and twigs from alder of small diameter classes.

percentage of error was great, many cut stems being unavoidably overlooked. Some of the dams studied have a shore line in excess of two miles, and islands that are inaccessible except when there is thick ice. When the ice is heavy enough to be used safely there is usually so much snow that the stumps are not visible. The figures obtained for the smaller species, chiefly alder and willow, are, therefore, omitted from this report. Since aspen is the primary food it is felt that its utilization by beaver should be given first consideration.

Notable beaver foods of less importance than aspen were alder, white birch, willow, red osier dogwood, and hazelnut. Alder, in the vicinity of beaver dams seldom exceeded two inches in diameter, so stems of the one and two inch classes were peeled and the bark and twigs weighed as described for the aspen. The curves in Figure 4 show the amount of food that can be expected from alders of small diameter. Where aspen was still easily obtainable only small numbers of the other species were cut, but as the aspen decreased larger quantities of the less choice foods were taken.

Birch and willow have not been studied in the same way so that their role in the beaver's diet cannot yet be interpreted in terms of the actual weight of food consumed.

Studies for determining the daily consumption of aspen by beavers have been started and results to date are included for their interest but not as settled criteria for management practices.

Two beavers, of 19 and 35 pounds, respectively, were fed aspen bark and twigs for a period of about a month; the average daily consumption for these animals was 33.2 ounces. The studies were terminated by a raiding bear that killed one beaver and wounded the other.

A beaver farmer, A. C. Tilden, located at Hill City, Minnesota, has been raising beavers for many years and he says that 80 animals eat the bark from a cord of aspen weekly. In order to obtain a weight factor for this consumption the writer had a cord of aspen, of the sizes fed by Mr. Tilden, peeled and the bark weighed. It amounted to 787.2 pounds. That quantity of bark fed to 80 beavers in a week would supply 22.5 ounces per animal per day. Until more figures on food consumption are available, however, no particular dependence for beaver management should be placed in those here presented.

CONCLUSIONS

1. Aspen is the most important of the food species of beavers in the Superior National Forest, with birch, alder, and willow next in rank.

2. The degree of utilization of aspen based on measurements of 456 trees was 36% and of waste 64%.

3. The greatest complete wastage occurs in trees between 4 and 6 inches in diameter because there is usually a heavier stand of these sizes and more of the cut trees lodge, thus preventing utilization.

4. Feeding experiences show that beavers consume between 22 and 33 ounces of aspen bark and twigs daily.

LITERATURE CITED

(1) BAILEY, VERNON
1927. Beaver habits and experiments in beaver culture, U. S. Dept. of Agr. Tech. Bull. 21.

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U. S. Biological Survey
Saint Paul, Minnesota

SEASONAL ABUNDANCE OF SOME PARASITES OF WILD DUCKS

W. Carl Gower

Animals feeding in or on the water are especially likely to be highly parasitized by helminths. The reason is that a large number of worm parasites pass some of their stages in aquatic animals. Ducks are no exception, being hosts to more than 100 species of trematodes alone.

In this report the prevalence (total and seasonal) and something of the host-parasite relationships are discussed for eleven genera of duck parasites. The data presented resulted from examination of 104 ducks during a period of one year. In calculating percentages of infection, species of ducks were not considered separately as there is practically no evidence of host specificity.

The examinations were made at the W. K. Kellogg Bird Sanctuary near Augusta, Michigan. About one-half of the ducks were obtained there, and the remainder from various localities in the State. The following species of ducks are represented in the host list: mallard (*Anas platyrhynchos*) both wild and domestic; black duck (*A. rubripes*); pintail (*Dafila acuta*); green-winged teal (*Nettion carolinensis*); blue-winged teal (*Querquedula discors*); widgeon (*Mareca americana*); lesser scaup (*Nyroca affinis*); greater scaup (*Nyroca marila*); ring-necked duck (*Nyroca collaris*); redhead (*Nyroca americana*); canvasback (*Nyroca valisineria*); and American goldeneye (*Glaucionetta clangula americana*).

The genera of parasites involved are as follows: (Trematoda), *Echinostoma*,

TABLE 1

COMPARATIVE SEASONAL INFECTION OF 104 DUCKS WITH HELMINTHS

	Spring	Summer	Fall	Winter	Total
Number examined	17	26	51	10	104
Number infected	13	22	42	8	85
Number negative	4	4	9	2	19
Per cent infected	76	84	82	80	80.5

TABLE 2

SUMMARY OF SEASONAL AND TOTAL PERCENTAGES OF INFECTION OF 11 GENERA OF HELMINTHS IN 104 DUCKS

	Spring Per cent	Summer Per cent	Fall Per cent	Winter Per cent	Total Per cent
Amphimerus	11.7	11.6	2	30	8.6
Cotylurus	5.9	27	41	10	28
Echinostoma	35	27	39	50	42
Maritrema	5.9	0	2	30	4.8
Prosthogonimus	17.5	0	27	20	18.3
Typhlocoelum	17.5	3.8	12	0	9.6
Zygocotyle	17.5	23	4	10	11
Fimbriaria	5.9	65	21	40	31
Hymenolepis	47	57	61	60	57
Tetrameres	11.7	31	4	10	12.5
Filicollis	5.9	3.8	12	0	7.7

Cotylurus, Prosthogonimus, Zygocotyle, Typhlocoelum, Amphimerus and *Maritrema;* (Cestoda), *Hymenolepis, Fimbriaria;* (Nematoda), *Tetrameres;* and (Acanthocephala), *Filicollis.* They are discussed in the order of prevalence.

TOTAL AND SEASONAL INFECTION

Total infection by seasons is recorded in Table 1. The average total infection for the year was 80.5%. The lowest period of general infection was during the spring and the highest in summer, with a gradual tapering off through the fall and winter, the entire range for the year, however, being only 8%.

The percentage of infection with each genus of helminths is shown in Figure 1, and a summary of the seasonal and total percentages of infection in Table 2.

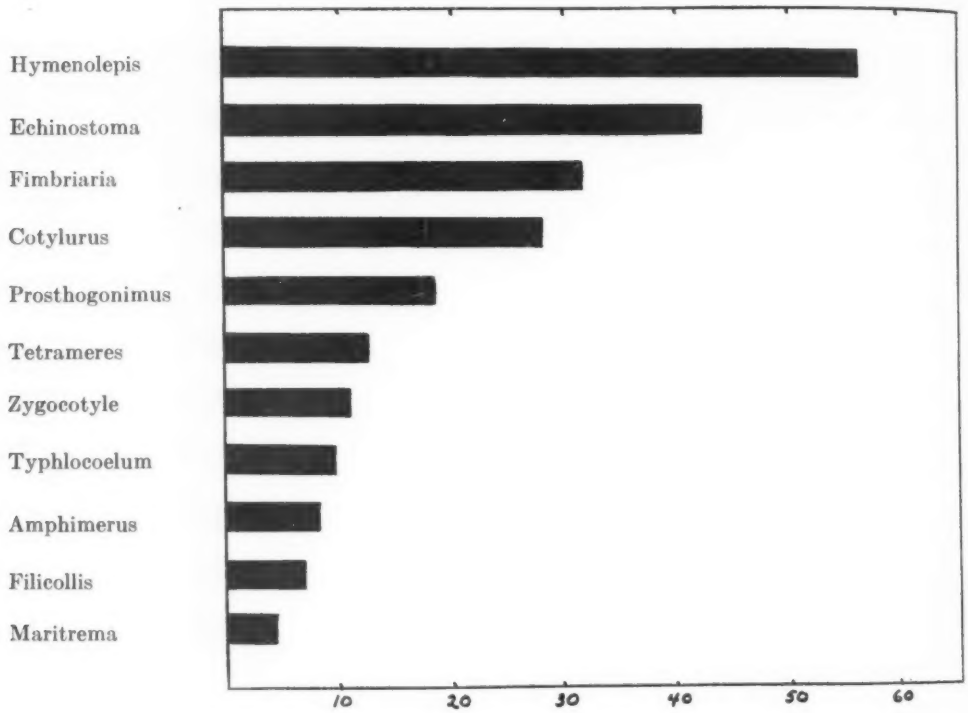

Fig. 1. Comparative rank of 11 genera of helminths in percentage of infection of 104 ducks.

INFECTION BY GENERA

Hymenolepis

The cestode genus *Hymenolepis* was the most prevalent of all the parasites. Seasonal infection (Fig. 2) ran 47% in the spring, 57% in the summer, 61% in the fall, and 60% in the winter. This genus is represented by at least five or six species which vary slightly in their ecology, but which are reasonably similar and for all practical purposes may be considered together. According to the known life histories, they use snails or crustacea as inter-

mediate hosts. It is doubtful whether this genus causes much damage to ducks, although Schofield (1932) reported *Hymenolepis coronula* as a serious parasite of young ducks. In this connection it may be said that any parasite is a potential pathogen, and given the right conditions may either directly or indirectly cause the death of the host. Such conditions may be due to starvation, disease, cold, or almost anything that would lower the

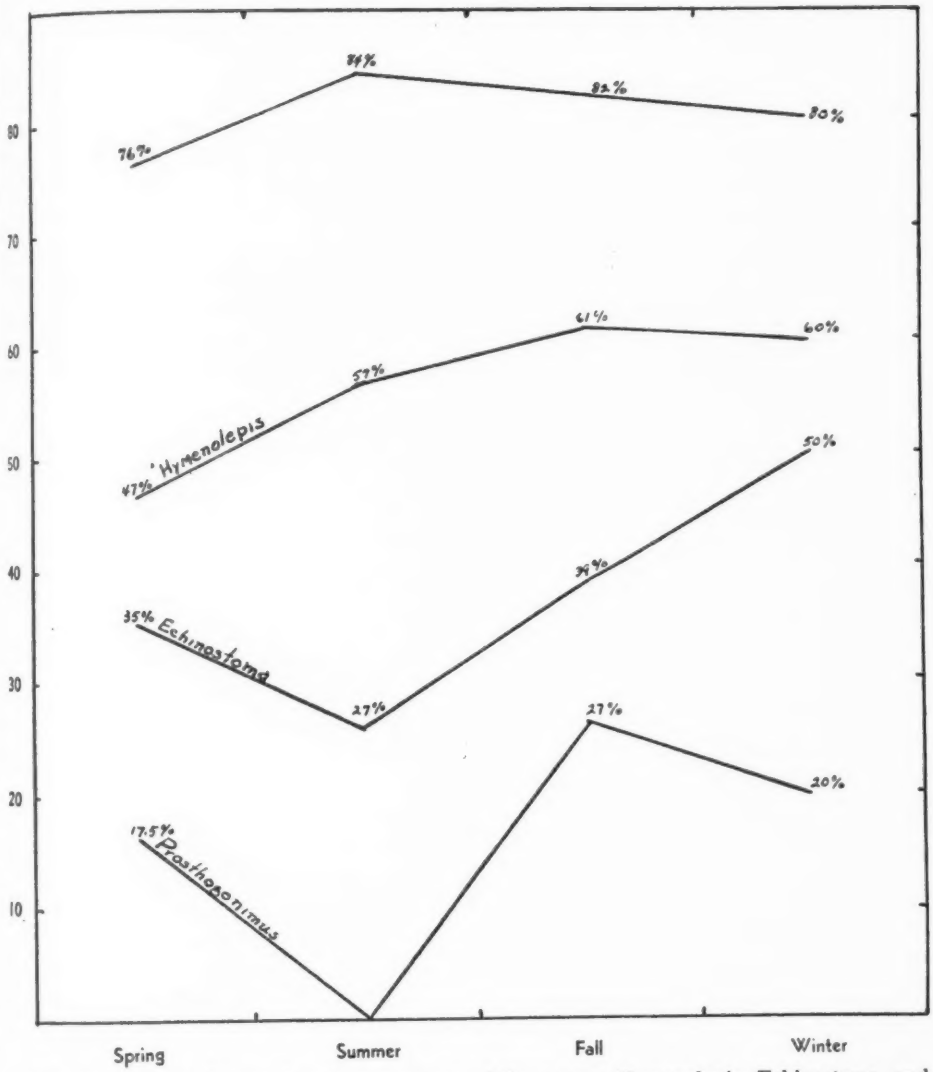

Fig. 2. Seasonal fluctuations in occurrence of the genera *Hymenolepis*, *Echinostoma*, and *Prosthogonimus*. The unlabeled curve indicates seasonal fluctuation in total infection by 11 genera of helminths.

resistance of the bird to the parasite. Young birds are more susceptible to parasitic infection than adults, and it is probable that most of the damage done by parasites is to immature birds.

Echinostoma

The genus *Echinostoma*, represented by a single species, *E. revolutum*, showed the highest rate of infection of any of the trematodes. The seasonal infection (Fig. 2) was: spring 35% summer 27%, fall 39%, winter 50%. This species seems to be one of the least harmful of duck parasites, almost never appearing in excessive numbers. In the present study no instance was found of its having caused any noticeable inflammation. Usually the larger specimens are in the colon, while the younger stages are found in the upper intestine. Occasionally three or four age groups of the worms were found in a single host. This parasite lives in a variety of both intermediate and final hosts (Johnson, 1920; Beaver, 1937). The metacercaria or infective stage lives for the most part in snails, but may also occur in tadpoles, and even fishes. Ducks undoubtedly are infected primarily from eating snails.

Fimbriaria

The genus *Fimbriaria* is represented by *F. fasciolaris*. This cestode infected 31% of all the ducks examined, the percentages by seasons being: spring 5.9%; summer 65%; fall 21%; and winter 40%. The drop in the fall percentage is probably insignificant, and more data would tend to smooth out the curve (Fig. 5). This worm is relatively large (9–10 inches maximum). It does not have true segments like most of the tapeworms, but is usually wrinkled in such a manner that the strobilus appears segmented. Another character which distinguishes *Fimbriaria* is the large pseudoscolex or head which is ribbon-like, and extends at a slight angle from the anterior end. Crustacea serve as intermediate hosts for this species. That the worms cause some losses among young ducks is unquestionable. In early summer they were present in the young ducks examined in almost incredible numbers, and in at least two or three cases the masses of worms were great enough to actually distend the intestines.

Cotylurus

The genus *Cotylurus* also is represented by a single species, *C. flabelliformis*, which was found in 28% of the ducks. The seasonal infection was: spring 5.9%; summer 27%; fall 41%; and winter 10% (Fig. 3). Van Haitsma (1930) found this species to use a variety of snails for both first and second intermediate hosts. He showed also that the adult worm has a very short life, remaining in a duck only a few days. In view of that fact the great variation in percentage of infection is easily explained on the basis of the greater accessibility of snails during summer and early fall, and of their relative inaccessibility during the winter. Since the worms remain only a week or so in the final host there is practically no carry over from one period to the next. In heavy infections, this worm may do considerable damage to the epithelium of the intestine, and may even cause some loss of blood. In general, however, it does not appear to be very pathogenic.

Prosthogonimus

The genus *Prosthogonimus* is composed of avian flukes usually found in the oviduct or bursa of Fabricius. The oviduct is infected only during the relatively short period when it is functional during the spring, and since the bursa is present only in immature birds (in ducks of 8 months or less), irregularity in abundance of this genus is marked (Fig. 2). Two species have been found regularly in this study,

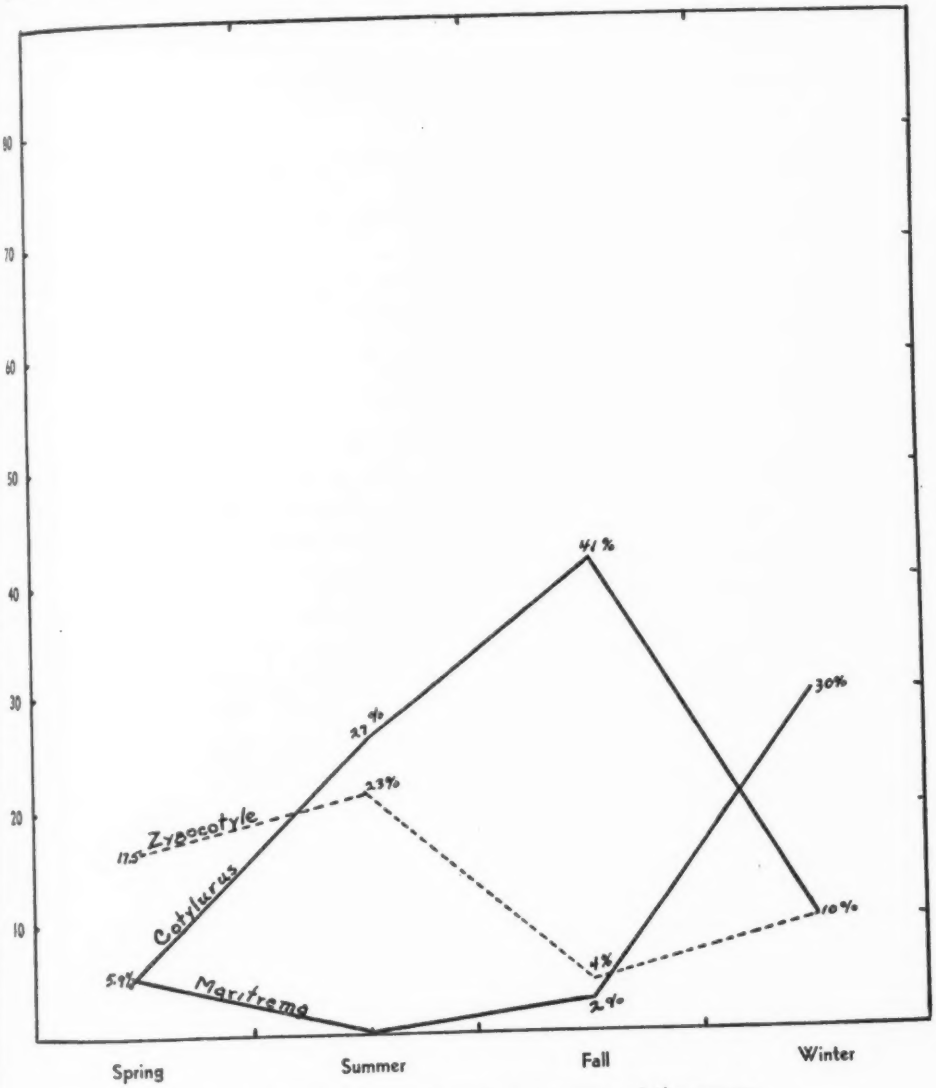

Fig. 3. Seasonal fluctuations in occurrence of the genera *Zygocotyle*, *Cotylurus*, and *Maritrema*.

one, *Prosthogonimus macrorchis*, only from the oviducts of laying females in the spring, mostly in May, and the other, *P. rudolphii*, entirely from the bursae of young birds in the fall.

The life cycle of *P. macrorchis* has been worked out in some detail. Kotlan and Chandler (1926) reported the infective stage of the fluke to occur in dragonfly naiads, and Macy (1934) determined the snail host to belong to the genus *Amnicola*.

There is relatively little data to show that this genus is ever very pathogenic to ducks. In breeding females, the irritation of the oviduct by large numbers of these worms would be suspected of affecting the normal production of eggs, and Kotlan and Chandler (1925) have described a severe pathology in one instance. On the other hand one duck, harboring 12 very large specimens of *Prosthogonimus*, was observed to lay a clutch of 11 eggs in the normal manner, and a female mallard with 48 fully mature flukes in the oviduct laid eggs.

Tetrameres

The genus *Tetrameres* (Nematoda) infected 12.5% of the ducks examined. The seasonal distribution was: spring 11.7%; summer 31%; fall 4%; and winter 10% (Fig. 5). This nematode lives in the glands of the proventriculus. The females are globular and dark red in color, the males being typically nematode in shape and white. The males are extremely hard to find. A crustacean serves as the intermediate host (Swales, 1936) and as will be noted the curve of seasonal abundance is more or less parallel with that of *Fimbriaria* having a similar life history. The worm may be pathogenic if present in excessive numbers which, however, seldom seems to occur.

Zygocotyle

The genus *Zygocotyle* is the only Amphistome reported from ducks. These flukes were found in small numbers in the caeca of the host. The total infection by this worm was 11%. Seasonal percentages of infection are: spring 17.5%; summer 23%; fall 4%; and winter 10% (Fig. 3). The life cycle depends upon snails of the genus *Heliosoma* (Willey, 1937; Gower, 1938). The cercariae encyst on aquatic vegetation, thus making theoretically possible infection of ducks at almost all times of the year except possibly in winter and early spring. The sudden drop in the autumnal rate of infection is, therefore, rather hard to explain. That this parasite causes any pathology in the host is doubtful.

Typhlocoelum

The genus *Typhlocoelum* is represented by two species, *T. cucumerinum* and *T. cymbium*. They are very closely allied, and may be distinguished solely by the form of the testes which are lobed in *T. cucumerinum*. Seasonal infection (Fig. 4) varied as follows: spring 17.5%; summer 3.8%; fall 12%; and winter 0%; the average being 9.6%. The life history involves snails of the genus *Heliosoma* (Szidat, 1932; Stunkard, 1934), infection resulting in the duck eating these mollusks. Normally the worms live in the trachea of ducks, but if present in large numbers may also be found in the nasal passage, lungs, air sacs, and body cavity. A heavy infection in a young bird can easily prove fatal; one such case has been observed.

Amphimerus

The genus *Amphimerus* is represented by one species, *Amphimerus elongatus*. This species infected 8.6% of all the ducks examined with the following seasonal distribution: spring 11.5%; summer 11.5%; fall 2%; and winter 30% (Fig. 4). It inhabits the pancreatic and liver ducts, and may cause serious trouble, especially in young birds. The damage seems to be indirect, operating by lowering the resistance of the bird

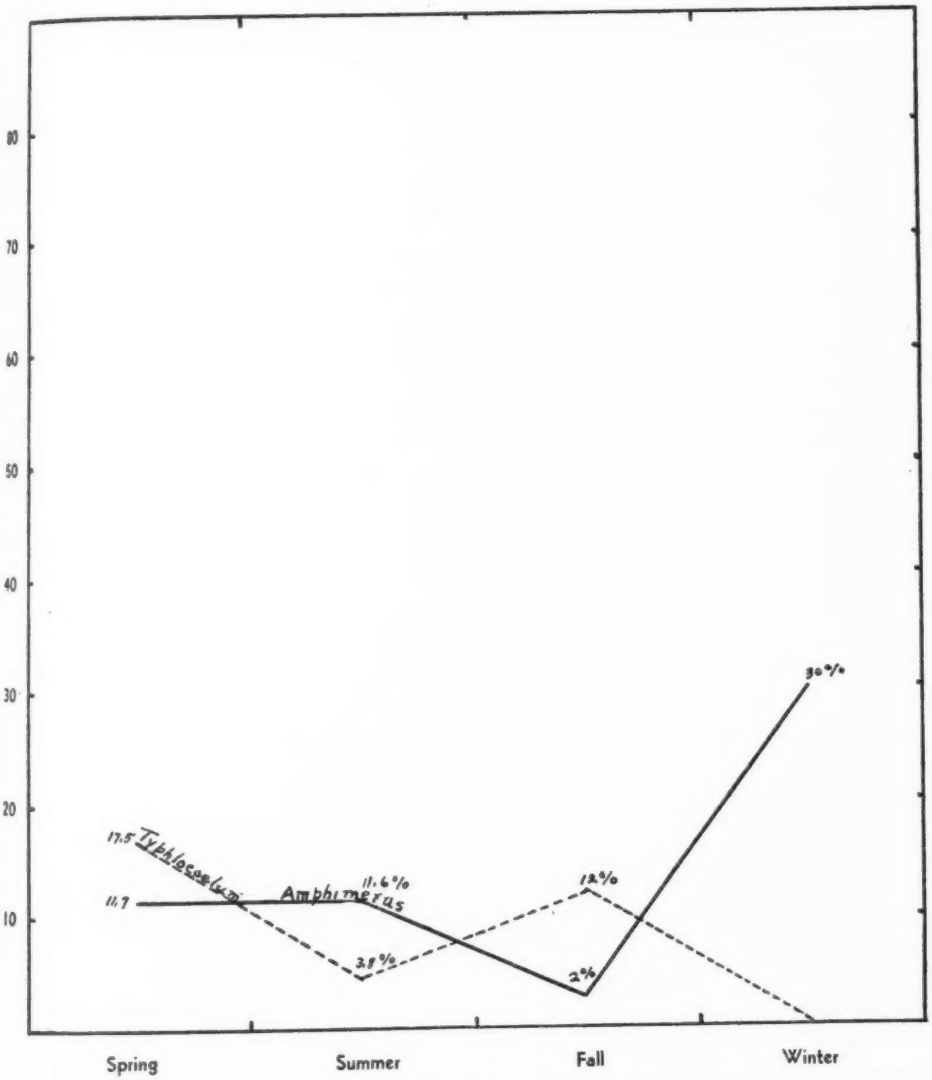

Fig. 4. Seasonal fluctuations in occurrence of the genera *Typhlocoelum*, and *Amphimerus*.

which usually dies from some other factor such as cold. The infective met a-cercariae occur in fish (Gower, 1938).

genus. The worms are cylindrical, yellowish in color, and are usually found just above the ilio-caecal valve

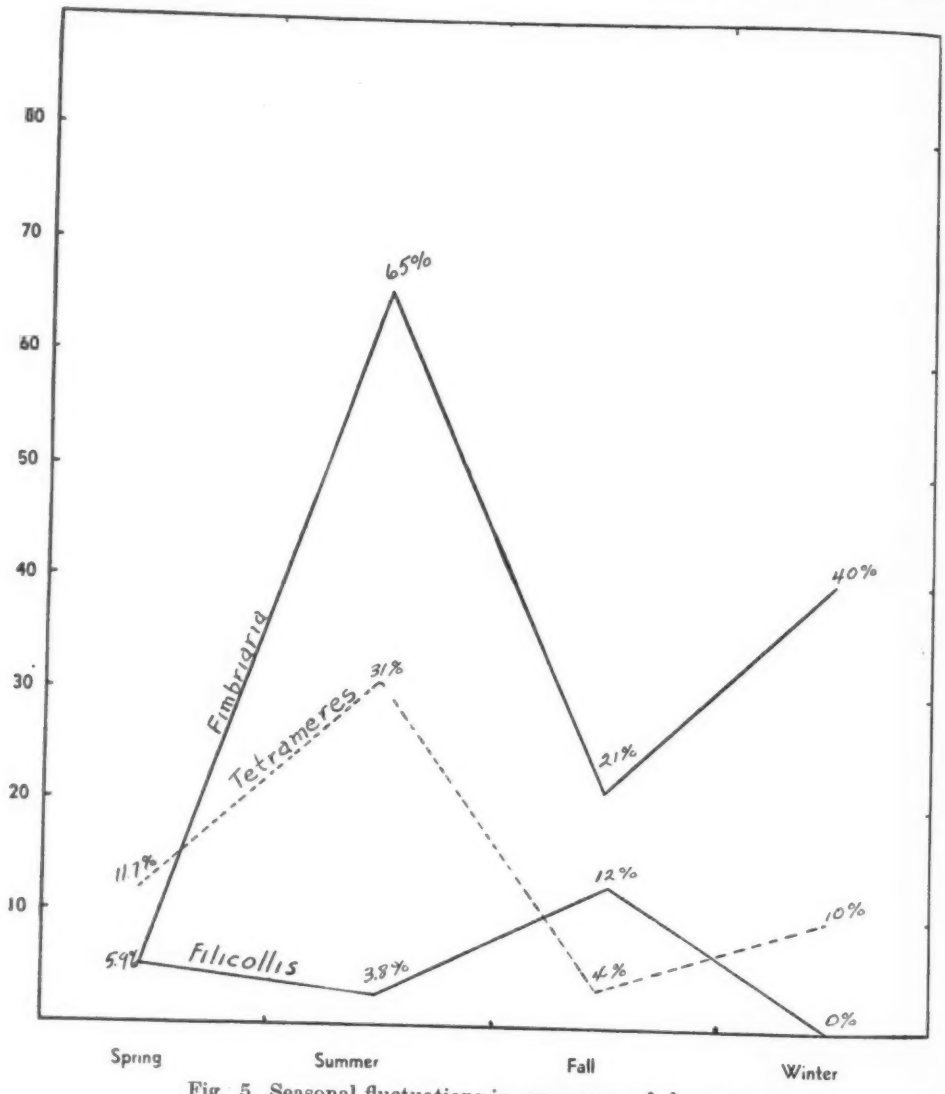

Fig. 5. Seasonal fluctuations in occurrence of the genera *Fimbriaria*, *Tetrameres*, and *Filicollis*.

Filicollis

The Acanthocephala or thorny headed worms were represented by this

in the small intestine of the host. 7.7% of the ducks examined were infected, but the worms were always in very

small numbers. The seasonal percentage was: spring 5.9%; summer 3.8%; fall 12%; and winter 0% (Fig. 5). The life cycle is unknown, but a crustacean probably serves as the intermediate host. Although *Filicollis* is not yet definitely associated with any pathology, the proboscis is often embedded in the intestinal wall to considerable depth, and may occasionally penetrate the wall, in which case a serious peritonitis might easily develop.

Maritrema

The genus is represented by a single species, *Maritrema nettae*. This is a very small trematode, and to date has been found only in goldeneyes and lesser scaup ducks (Gower, 1938). The total infection was only 4.8%. Seasonal percentages were: spring 5.9%; summer 0%; fall 2%; and winter 30% (Fig. 3). Although its life cycle is not known, this species probably uses crayfish for a second intermediate host. If this is true the high winter percentage is reasonably explained, for the wild ducks in Michigan during the colder part of the year feed in running streams where they might obtain crayfishes. These worms were usually in large numbers but no pathology was found in connection with them.

DISCUSSION

Ecologically, the most important single factor in host-parasite relationships seems to be the manner in which the infective stage of the parasite is available to the final host. The duck parasites discussed here fall into five groupings on this basis—the larvae may encyst: (1) free, i.e., on vegetation, etc.; (2) in crustaceans; (3) in snails; (4) in aquatic insects or their larvae; and (5) in fishes. Thus, the biology of the host in which encystment occurs is most likely to control infection in the final host.

One factor that has a great deal of importance is the degree of specificity of the worm for the second intermediate host. For instance the fluke, *Echinostoma revolutum*, apparently encysts in almost any kind of snail, as well as in tadpoles, catfishes, etc. So far as ducks are concerned, however, snails constitute the principal source of infection. The various species of snails reaching peak numbers at different times of year, afford a constant source of infection from this parasite. On the other hand, a worm which is rigidly host specific for the second intermediate host, as *Typhlocoelum* seems to be, is much more seasonal in distribution with respect to the final host.

LITERATURE CITED

BEAVER, PAUL C.
1936. Experimental studies on *Echinostoma revolutum* (Froelich) a fluke from birds and mammals. Ill. Biol. Monogr. 15 (1): 1–96.

GOWER, W. CARL
1938. Studies on the trematode parasites of ducks in Michigan with special reference to the Mallard. Mich. Agr. Exp. Station Memoir 3:1–94

HARKEMA, R.
1936. The parasites of some North Carolina rodents. Ecol. Monogr. 6: 151–232.

JOHNSON, J. C.
1920. The life-cycle of Echino-

stoma revolutum (Froelich). Univ. Calif. Publ. Zool. 19: 335–388.

KOTLAN, A. and W. L. CHANDLER
1926. A newly recognized disease (Prosthogonimaisis) of fowls in the United States. Jour. Am. Vet. Med. Assn. 67: 756–763.
1927. On the role played by Dragonflies in the transfer of *Prosthogonimus*. Jour. Am. Vet. Med. Assn. 70: 3–7

MACY, RALPH W.
1934. Studies on the taxonomy, morphology, and biology of *Prosthogonimus macrorchis* Macy, a common oviduct fluke of domestic fowls in North America. Univ. Minn. Agr. Exp. St. Tech. Bul. 98.

MCMULLEN, D. B.
1937. The life histories of three trematodes parasitic in birds and mammals, belonging to the genus *Plagiorchis*. Jour. Parasitol. 23 (3): 235–243.

PRICE, E. W.
1928. Host relationships of the trematode genus *Zygocotyle*. Jour. Agr. Res. 36 (10): 811–914.

SCHOFIELD, F. M.
1932. Heavy mortality among ducklings due to *Hymenolepis coronula*. Ann. Rept. Ontario Vet. Coll. 1931: 49.

STUNKARD, H. W.
1934. The life cycle of *Typhlocoelum cymbium*, (Diesing, 1850) Kossack, 1911. Bul. Soc. Zool. France, 59: 447–466.

SWALES, W. E.
1936. *Tetrameres crami* Swales, 1933, a nematode parasite of ducks in Canada. Canadian Jour. Res. 14: 151–164.

SZIDAT, L.
1932. Zur Entwicklungsgeschichte der Cyclodoeliden. Der Lebenszyklos von *Tracheophilus sisowi*. Zool. Anz. 100: 205–213.

VAN HAITSMA, J. P.
1930. Studies on the Trematode family Strigeidae (Holostomidae) no. XXII. *Cotylurus flabelliformis* (Faust) and its life history. Papers Mich. Acad. Sci. 13: 447–483.

WILLEY, C. H.
1937. The development of *Zygocotyle* from *Cercaria poconensis* Willey, 1930. Jour. Parasitol. 23 (6): 571.

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COCCIDIOSIS IN MUSKRATS INFLUENCED BY WATER LEVELS

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In a recent article (2) Dr. Paul L. Errington discusses drowning as an important cause of death among young muskrats during times of high water. Experience has shown that subnormal water levels on marshes likewise are unfavorable to the welfare of the muskrats. Long periods of lowered water level may so modify the amount and types of desirable vegetation as to cause a serious shortage of food. This, however, is only part of the loss that a muskrat population may sustain during times of radically lowered water levels.

Usually the feces of muskrats are deposited in water of sufficient volume or movement to dissipate the pollution effectively and to prevent the accumulation of manure in the passages frequented by the animals. Were it not for this natural dilution and washing away of feces by the flowage of streams or the surge of the tides, it is probable that many diseases incident to fecal contamination would be destructive to muskrats. Biologists describe these animals as being very cleanly in their habits, and anyone who has studied muskrats in natural marshes is impressed with their avoidance, whenever possible, of places carrying heavy pollution.

At times when the water level falls below normal, leaving many of the muskrat canals above the surface, a very different situation exists. The floor of the passageways become a soft muck composed of the partially dried soil, decaying organic matter, and feces of the muskrats. As the animals walk through this it is impossible for them to avoid contaminating their feet and bodies with organisms that thrive under such conditions. Likewise food plants carried or dragged through the trails are subjected to contamination.

In large groups of animals it is not unusual to find at any time a few carrying various parasites or other disease-causing organisms. One protozoan disease—coccidiosis—seldom becomes serious in muskrats under normal conditions, but in partially dried marshes where the droppings are not washed away, heavy infestations take place. The coccidial oocysts passing from the digestive tract with the feces of affected individuals become very numerous in the mud of the runways and former canals frequented by the animals. Massive infestations develop, and great mortality has been noted after several weeks of drought on a marsh. Trappers report a decrease of three-fourths in the muskrat population within a few weeks from this cause.

Lesions found in muskrats affected with coccidiosis may be described as grayish-white granular areas in the liver and inflammation in the small intestine. According to the writer's observations, the enteritis may not be as important as the destruction of liver tissue. Although either of these lesions alone, when sufficiently extensive, may cause death, most of the deaths observed seemed more properly ascribed to the coccidiosis of the liver.

Martin (3) has described a species of coccidium in muskrats as *Eimeria ondatra-zibeticae*. His observations show a rather wide variation in the dimensions of the oocysts, and Becker (1) suggests the probability that more than one species of coccidia are parasitic in these animals. From available information we are unable to say which species of coccidium causes the destructive liver infestations in muskrats, and there is evident need for further research. Little is known of protozoan nfections in the wild, and research may readily be conducted on the commonly encountered coccidia.

Muskrat coccidiosis can probably be controlled by manipulation of the water level, but oftentimes this may not be feasible. The requirements for effective elimination of losses are not well understood. For example, it is not known how long the water level may be below normal before the disease develops. Neither is it known what effects temperature and specific qualities of the water and mud have on the development of the coccidial oocysts.

LITERATURE CITED

1) BECKER, ELERY R.
1934. Coccidia and Coccidiosis of Domesticated Game and Laboratory Animals and of Man., p. 62, Collegiate Press, Inc., Ames, Iowa.

(2) ERRINGTON, PAUL L.
1937. Drowning as a Cause of Mortality in Muskrats., Jour. of Mammalogy, vol. 18, no. 4, 497-500.

(3) MARTIN, H. M.
1930. A Species of Eimeria From the Muskrat, *Ondatra zibethica* (Linnaeus), Arch. f. Prot., 70: 273–278.

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WILDLIFE EXTENSION ACTIVITIES IN MICHIGAN

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During recent years there has been an increase in requests from farmer and sportsman groups in Michigan for information concerning wildlife problems. In this, as in other states, the situation resulted in considerable extension work being carried on by the conservation department. Where there was sufficient demand, education divisions were formed. While this arrangement has in general proved very satisfactory, it has not fulfilled require ments as to technical information on the life histories and habits of wildlife, and as to social problems involved in its maintenance. Consequently, in Michigan two members of the game division have devoted part of their time to extension activities, and an extension specialist was employed to work cooperatively between the Game Division of the Department of Conservation and the Extension Service of Michigan State College.

This paper is written for the purpose of informing individuals in other states about wildlife extension work in Michigan with the hope that it may provoke suggestions and criticisms, and result in an enriched program wherever this work may be inaugurated.

The wildlife extension problems confronting us are comparable to those of neighboring states. With increase in leisure time and efficient mechanical transportation, nearly every fourth man in Michigan travels to local or distant areas to enjoy a few days of hunting. In many districts topographical changes since colonization have been unfavorable to wildlife in general, and especially to farm game. There are possibly more game animals available to the hunter in Michigan today than during any previous period, but the game per hunter ratio is no longer the same, and some of the species which our fathers used to hunt are not now available in desirable quantities. Fur bearers have no doubt suffered more from increased demand than have game animals.

It is also true that certain species of animals have been killed in large numbers due to erroneous opinions concerning their food habits. Hawks, owls, skunks, and woodchucks are examples, and their treatment is an added incentive to educational work.

In addition to these factors, there has arisen a social problem which threatens to be even more important. Concentration of certain popular species of wildlife into localized areas, and increase in the number of hunters there have resulted in considerable conflict between sportsmen and landowners. Lack of realization by sportsmen that they are responsible to the landowner for permission to take game, even though this game is in theory the property of the state, aggravates the trouble. The result in many localities has been a resentful attitude on the part of farmers toward both sportsmen and wildlife. Frequently landowners desire that wildlife disappear as soon as possible so that trespass difficulties will cease. The need for an educational program is apparent.

In the past, very little on wildlife management has found its way into the biology or land use courses in our public school system. In fact, only recently have such courses been offered to students in our teacher-training institutions. Consequently any educational program involving wildlife and its management must care for such fundamentals as clear explanation of the problem, definition of the concepts that are to be presented, and securing of adequate aid in developing the concepts, before it can proceed with actual presentation of the material.

Extension work in Michigan is being conducted for three types of individuals—the sportsman, the farmer, and the youth. The objectives to be stressed in each case and the means of bringing about an understanding of the problems are outlined below:

Group	Objectives	Procedures
Youth	(a) Appreciation of wildlife. (b) Understanding of factors which influence wildlife populations. (c) Participation in actual wildlife management in local areas.	Show motion pictures of Michigan wildlife. Hold wildlife exhibits in connection with community activities. Urge visits to a zoological park. Urge the teaching of conservation in the public schools. Take field trips to wildlife demonstration areas. Prepare informational matter on wildlife for school classes. Outline 4-H Club and Future Farmer wildlife projects. Present interviews or interesting facts in radio programs. Describe wildlife projects at Youth Achievement meetings. Show maps illustrating what happens to a covey of birds over a year's period. Suggest modifications that could have prevented losses. Furnish educational leaders with bibliographies on wildlife and its management. Visit 4-H Club and Future Farmer projects to offer advice and encouragement.
Farmer	(a) Appreciation of wildlife and understanding of its value to his land. (b) Realization that the landowner is key man in wildlife development. (c) Understanding of factors influencing wildlife populations. (d) Adaptation of wildlife management to land use. (e) Cooperation with Conservation Dept. and sportsmen to form game management area.	Show motion pictures of Michigan wildlife. Discuss, with aid of charts and slides, the food habits of animals. Present a report of the fur taken in Michigan and show areas reporting most fur. Foster exhibits of wildlife in connection with community activities. Stress recreational and companionship value of animals. Show film illustrating food and cover requirements of wildlife.

Group	Objectives	Procedures
		With films or slides show how good farming practices are related to game management. Set up demonstrational farms where wildlife management may be seen. Make personal visits to farms where wildlife problems exist. Explain the organization and operation of "Farm Cooperative Hunting Clubs" and show how the Conservation Department can aid. Distribute publications on game management. Release timely newspaper articles or radio programs on any of above topics. Refer specific wildlife problems to technicians in the State College or the Conservation Deparment.
Sportsman	Appreciation of the following facts: (a) Much wildlife may be on good farm land which probably will never be state owned. (b) Legislation is not a complete remedy for present ills. (c) Wildlife is now being produced incidental to and in spite of agriculture. (d) Increase in wildlife populations depends upon farmers' attitudes and actions. (e) A variety of factors influence wildlife populations. (f) There is necessity for close cooperation between Farmer, Sportsman, College, and the Department of Conservation. (g) There is imperative need for experimental areas and further research.	By using a state soils map show where best soil is located and how it is correlated with game populations. Review past legislation showing that restrictions, predator control, refuges, sanctuaries, and artificial propagation have not solved wildlife problems. Describe landowner's attitude toward producing wildlife on farms to be removed chiefly by "Outsiders" who take such game without permission. Show film illustrating cover and food requirements of wildlife. Show motion pictures illustrating life histories of different species of wildlife. Review damage to crops by wildlife. Explain the farm game management areas where hunting is controlled and show how sportsmen can cooperate in controlling trespass and in game management. Stress the need for youth educational programs. Call attention to some of the unsolved problems concerning food habits, life histories, ecological relationships, and management of important species of wildlife. Release newspaper articles and radio programs on any of above topics.

As time progresses new methods of procedure no doubt will be developed. Those outlined above have been tried in Michigan with some success. There is, as one might expect, a considerable overlapping of objectives for the three groups and a single method of procedure may be adequate or even necessary for all, especially in mixed meetings.

At the present time, stress should be placed on the development of aids to procedure. Bulletins must be written, bibliographies assembled, motion pictures taken, film strips made, maps drawn, and newspaper articles and

radio scripts prepared. Demonstrational areas are being developed by both the Department of Conservation and the Soil Conservation Service, with emphasis centered on efficient land use. While it is agreed that certain farm practices, such as the removal of fence rows and brush piles, and drainage may be detrimental to wildlife, there is slight hope that landowners will abandon them to favor wildlife as long as they yield some economic return. Wildlife is considered by farm folks as secondary to agriculture because it does not bring a monetary remuneration. Under present conditions it can not be expected that farmers will leave cover or land suitable for farming or spend much labor or money in planting to improve areas already favorable to wildlife. On the Kent Game Management Area, where several years ago the Department of Conservation made plantings for wildlife in cooperation with farmers, it was found that during the dry seasons of 1935 and 1936 when pasture was short, the farmers turned their stock into these areas, causing the destruction of the plantings. These same men are wildlife enthusiasts, but economic stress at that time overcame their appreciation of the "esthetic" and "companionship" value of the wildlife. The same thing occurred in previously unpastured woodlots.

Farm people, like everyone else, have been taught from youth that neatness and cleanliness of self and home are associated with success. Brushy fence rows and weedy roadsides and ditch banks have been considered by good farmers as not only wasting land, but also as indicating untidiness and shiftlessness. The simple wire and the electrified fences have accelerated the removal of hedgerows. Extension work should encourage correlation of wildlife management with good farm practices, and also point out the value of brushy fence rows and other cover areas, so that the farmer who really does want a greater wildlife concentration, may govern his activities accordingly.

Wildlife Extension work must progress slowly, and on a thoroughly practical basis. It must have merit to win acceptance by County Agricultural Agents with already overloaded schedules. In Michigan, therefore, every effort is being made to supply adequate information for county agents, 4-H Club leaders, and teachers in the public schools. Later it will be most desirable to provide conservation education for prospective teachers in our training institutions. Any educational movement is a slow process and Wildlife Extension education fully promises to be no exception to the rule.

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AIDS TO THE IDENTIFICATION OF MOLE AND SHREW HAIRS WITH GENERAL COMMENTS ON HAIR STRUCTURE AND HAIR DETERMINATION

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Until recently there has been a dearth of information of a comparative nature upon which to build a system of hair identification. This situation is no doubt due in large measure to the extreme difficulty of conveying accurate ideas of hair characters by means of descriptions. As a result, most hair identifications have been made by specialists who learned the identification-value of the hair characters by the long, tedious method of comparing unknown, with accurately identified, samples. This necessitates much patience, long practice, and an extensive reference collection of hairs. There is a real need for the definition and illustration of diagnostic characters of hairs and the preparation of keys that may be used successfully by others than specialists. The present paper is an attempt to satisfy this need for the groups of moles and shrews by means of keys, camera lucida drawings, and short comments.

Application of Knowledge

Aside from its potential use in taxonomic studies to ascertain mammal relationships, knowledge of hair structure has direct value in the fur industry, in crime detection, and in economic ornithology and mammalogy. Its importance to the first two is quite apparent, but its application in the latter may require some explanation. To ascertain the food habits of such carnivorous animals as hawks, owls, eagles, coyotes, wolves, opossums, mountain lions, and foxes, it is necessary to analyze the contents of many stomachs, droppings, or pellets. Hair very often remains undigested and is frequently the only clue to the identity of the source of an entire meal. It resists remarkably well the digestion of practically all carnivores except the owls. A knowledge of hair structure effectively facilitates food habits investigations and offers a basis for more accurate and complete studies of predation and its effect on prey species. With more and more emphasis being placed by all conservation agencies upon the necessity of determining the influence of one form of animal life upon others and upon man's interests, hair identification takes on added importance.

Factors Affecting Hair Structure

The basic character of hair is determined primarily by hereditary factors. The similarity of hair structure in closely related species would seem clearly to indicate this. The influence of environment on hair structure, however, is definite and in many instances so alters hair features as almost totally to obscure the usual diagnostic characters. The physiological condition of the animal caused, among other things, by seasonal adjustment, disease, age, and food is probably the most important factor other than heredity influencing

the character of the hair. The seasonal loss and gain of underfur in such ground squirrels as *Citellus nelsoni* and *C. spilosoma* and the changes in the coats of penned animals fed different foods serve as examples of the action of this factor. Environmental influences in the main do not seriously alter those basic characters that are of value in the identification of hairs to families or genera. They do, however, in many cases materially alter features which might otherwise be used in making specific determinations and to that extent make difficult, if not impossible, the designation of constant characters that may be relied upon to identify definite species.

REVIEW OF HAIR CHARACTERS AND HAIR TYPES

Preliminary to a consideration of mole and shrew hair, it seems advisable to review briefly the elements of hair structure in general. Most mammals develop several types of hair on their bodies. These, unfortunately, are not always distinct and confusion may arise as to what type a particular hair belongs.

Types of body hair

There are several classifications of hair types, but the simplest is perhaps the most useful for purposes of identification. With some experience, there should be little difficulty in allocating any hair to one of the following two groups: (1) Hairs usually sensory in function, such as whiskers and nasal hairs; and (2) all others. The latter group is the more important from the standpoint of identification because it includes hairs that vary considerably in structure and appearance and those the worker is most frequently called upon to name. Highly specialized hairs of this group, such as the foot hairs of rabbits, porcupine quills, and hog bristles, are easily identified as distinct from other hairs.

For convenience, the normal coat hairs may be grouped according to form into three types: (1) Heavy overhairs which are normally longer, straighter, and more robust throughout their length than the general coat in most mammals. In some, however, notably deer, kangaroo rats, and pocket mice, the heavy overhairs are nearly parallel-sided and outnumber those of the other types; (2) curly overhairs which are usually enlarged only in the distal third or half of their lengths, the basal portion being decidedly weaker and more flexible; and (3) furhairs which are uniformly weak and flexible except at the tip and base. These are quite similar to the flexible part of the curly overhairs, especially in mole and shrew pelages. Figure 1 illustrates these hair types diagrammatically.

The structural elements of hair

The component parts of hair are termed cuticle, cortex, medulla, pigment, and air cells. The use of a compound microscope is essential to observe these to best advantage. Their relative positions are illustrated in Figure 2.

The *Cuticle* is the outer part of hair and is composed of keratinous scales which may be of several different sizes and forms even on the same hair. Because of this variability which is believed to bear some relation to the thickness of the hair, and because the

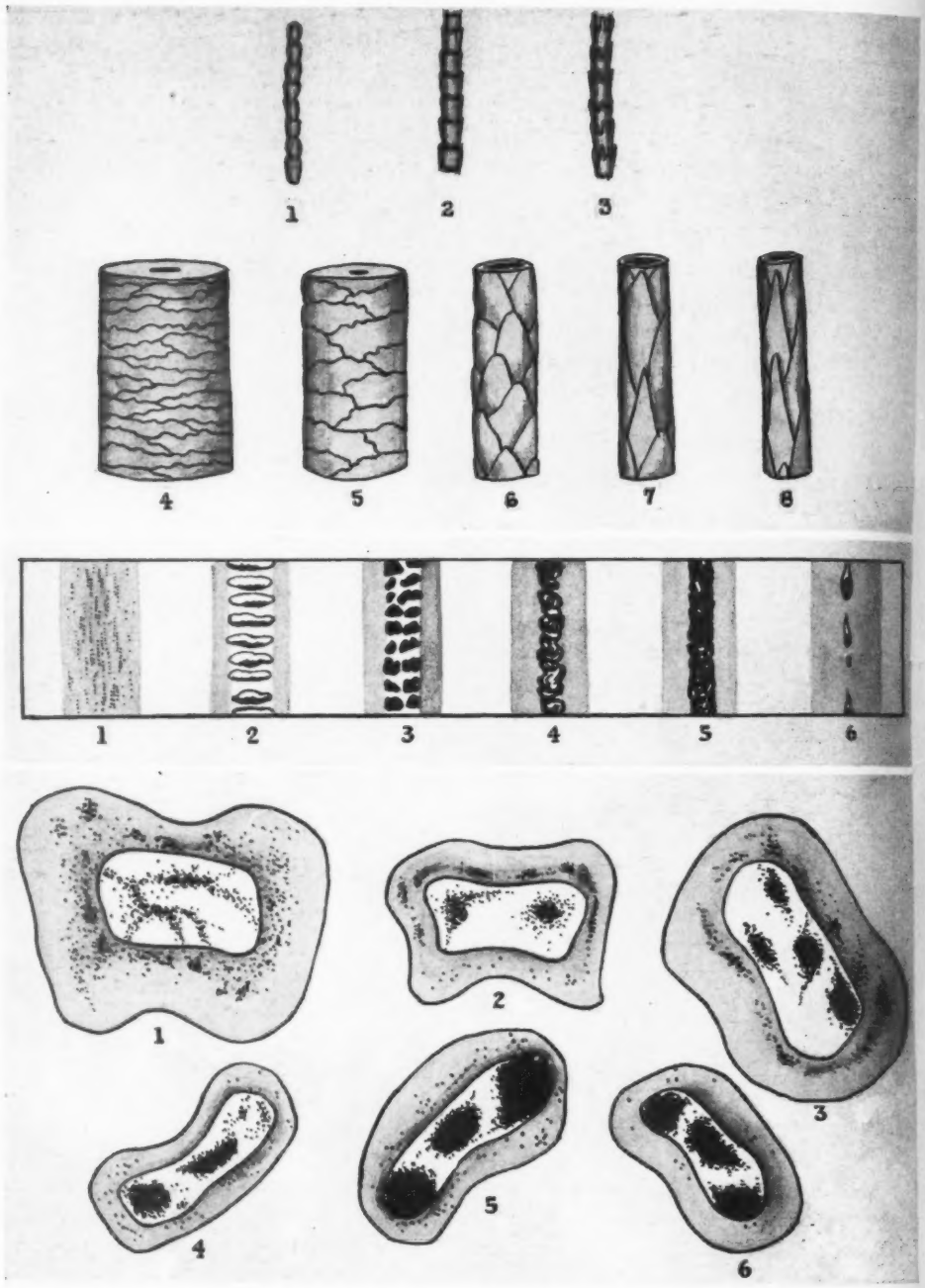

Plate 23

A. (*Upper*)—Cuticular scales. Coronal Scales: 1, Simple, 2, Serrate, 3, Dentate; Imbricate Scales: 4, Flattened, 5. Crenate, 6, Ovate, 7, Elongate, 8, Acuminate. (Diagrammatic sketches based, except for the acuminate type, on mole, shrew, and bat hairs.)

B. (*Middle*)—Types of medullae. 1, Hair without medulla; types of medullae: 2, simple, 3, compound, 4, globular, 5, continuous, and 6, fragmental. The relation of medulla diameter to that of the hair at the widest part is often useful in identification.

C. (*Lower*)—Cross sections of mouse hairs: 1, lemming (*Lemmus*), 2, red-backed mouse (*Clethrionomys*), 3, meadow mouse (*Microtus*), 4, white-footed mouse (*Peromyscus*), 5, harvest mouse (*Reithrodontomys*), and 6, grasshopper mouse (*Onychomys*). Approximately ×525.

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scales are somewhat difficult to observe, they are, when considered alone, unreliable for the identification of many mammalian hairs. In certain groups, however, such as the bats, in which the scales are prominent, they afford important identification characters. The cuticular scales are of two general types, coronal and imbricate. The coronal scales completely encircle the hair shaft and are classed according to the nature of their distal edges as simple, serrate, and dentate (Plate 23-A, 1–3). They are usually found on the finer hairs and on more slender portions of robust hairs. The imbricate scales appear not to encircle the hair but to overlap one another. They may be classified according to shape as flattened, crenate, ovate, elongate, and acuminate (Plate 23-A, 4–8). There is some correlation between the character of the scales and the diameter of the hair, but this as yet has not been thoroughly studied.

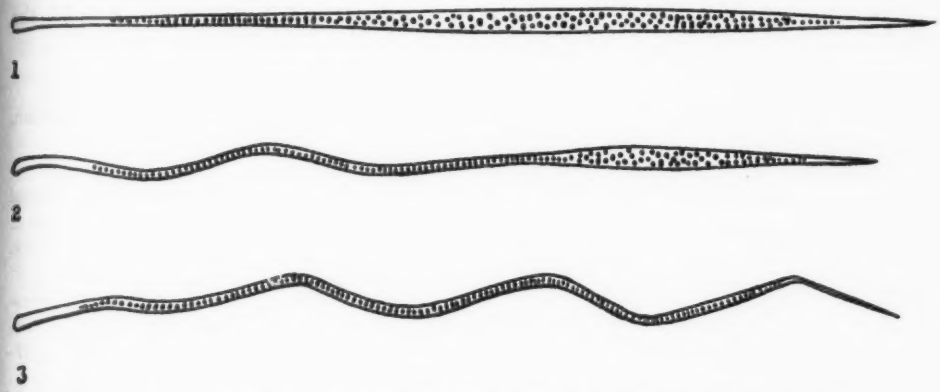

Fig. 1. Types of body hair. 1, Heavy overhair; 2, Curly overhair; 3, Furhair.

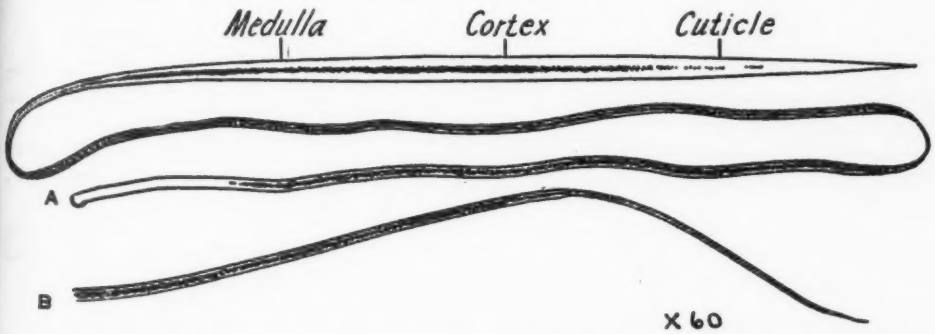

Fig. 2. Structural elements of hair. A, Overhair; B, Furhair, showing type of tip characteristic of moles and shrews. Pigment occurs as granular masses in the medulla, and as granules, and diffusely in the cortex. The air cells in the medulla are easily recognized.

The *Cortex* which often constitutes

the greater portion of the overhair consists of elongated cells, and if pigment be absent, appears as a hyaline encasement of the medulla. The combined diameter of the cortex and cuticle compared to that of the medulla is a useful character in identification. The distribution and character of cortical pigment also is of considerable specific significance.

The *Medulla* is composed of loosely arranged cells forming the central axis or core of the hair. Its most noticeable components are the pigment masses and the air cells which occur either singly or anastomosed to form a labyrinthine column. The medullary pigment apparently occurs one mass to an air cell; thus, when the air cells are numerous, closely compacted, and heavily pigmented, the medulla has the appearance of a solid core. The shape and arrangement of these medullary structures are useful in identification. Several types of medullae are illustrated in Plate 23-B.

Hair Shape is often an important aid in distinguishing between the hairs of closely related mammals. In the mice of the family Cricetidae for instance, the meadow mouse (*Microtus*), red-backed mouse (*Clethrionomys*), and lemming (*Lemmus*) have pelages of the curly overhair type, while the white-footed mouse (*Peromyscus*), harvest mouse (*Reithrodontomys*), and grasshopper mouse (*Onychomys*) have coat hairs in longitudinal aspect more like the heavy overhair illustrated in Figure 1, 1. The shape of the hairs in cross section (Plate 23-C) reflects this distinction between the hairs of these subfamilies.

It is the character of the above mentioned structural units and the differences in hair shape that serve as criteria for the microscopic identification of mammalian hairs here considered. For further information on hair structure and hair types reference may be made to specialized medical books and the following articles:

DANFORTH, C. C. and G. C. DANFORTH
1908. Heredity of hair form in man. Am. Nat., v. 42.

DANFORTH, C. H.
1925. Studies on hair with special reference to hypertrichosis. Arch. Dermatology and Syphilology, Am. Med. Assoc., 11(12).
1925. Hair in its relation to questions of homology and phylogeny. Am. Journ. Anat., 36, Sept., 47–68.
1926. The hair. Nat. Hist., 26(1).

GLAISTER, JOHN
1931. A study of hairs and wool belonging to the mammalian groups of animals including a special study of human hair considered from the medico-legal aspect. Egyptian Univ. Fac. Med. Publ., 2, Misr. Press., Cairo.

HAUSMANN, L. A.,
1920. The microscopic identification of commercial fur hairs. Sci. Mo., 1, Jan.
1920. Structural characteristics of the hair of mammals. Am. Nat., 44, Nov–Dec.
1920. Mammal fur under the microscope. Journ. Am. Mus. Nat. Hist., 20(4).

MOLE AND SHREW HAIRS

General character

Mole and shrew pelages are quite unlike those of other groups of mammals. They are soft and plush-like in texture and are often enriched by a glossiness, especially in some of the moles (genera *Scapanus* and *Scalopus*) that distinguishes them at once from other short-

haired furs. A microscopic examination of mole or shrew pelage reveals that the characteristic texture is produced by short, intertwining hairs of rather uniform lengths. Jackson has pointed out that such a pelage may be "a distinct advantage to a subterranean mammal" because the hair can "be rubbed either forward or backward with little friction."[1] Others have suggested that such a coat is waterproof and provides buoyancy by holding minute bubbles of air.

Distinction from those of Bats and Mice

The furhairs of moles and shrews possess lengthened whiplike tips (Fig. 2-B and Fig. 3) which distinguish them from those of bats and mice. As further aids in the separation of the hairs of these animals, the following differences may be cited: Overhairs of bats do not have a definite medullary column, those of insectivores and mice do; cuticular scales are very prominent on bat hairs, but obscure on the hairs of the other two groups; there are usually more than three pigment masses transversely at the widest hair diameter in the medullae of mouse overhairs, while in mole and shrew overhairs the usual number is one, three never having been found in those so far examined.

Fig. 3. Tips of furhairs of Florida short-tailed shrew (*Cryptotis floridana*), showing the long flagellum-like ends which are so characteristic of mole and shrew furs. Approximately ×50.

[1] Jackson, H. H. T. A review of North American moles. North American Fauna, No. 38, Sept. 1915, Washington, D.C., p. 11.

Furhair

The furhairs are always shorter, finer, and more abundant than the overhairs in the pelages of both moles and shrews. This is a condition quite different from the fur-overhair relationship prevailing in some mammals. In the ground squirrels *Citellus nelsoni* and *C. spilosoma*, for instance, nearly all of the fur is lost during the summer months, while in the pocket rats and pocket mice (Heteromyidae), the fur is generally poorly represented in both winter and summer.

Except in length, there are few differences between mole and shrew furhairs. Other characters such as the scale structure, hair diameter, and general relationship of structural elements, both in longitudinal and cross-sectional aspects are so similar that the differences do not have much value in identification. A description of the fur of moles, therefore, will suffice also for that of shrews, except in regard to length. Furhairs of moles are seldom under 8 mm. long, while those of shrews, except in the tundra shrew (*Sorex tundrensis*), are usually less than 8 mm. The diameter of the furhairs averages about 12 microns, and of their medullae nearly 10 microns. The hairs are terete appearing parallel-sided, except at the tips and bases and where they are

twisted or bent. The long, whiplike tips (Fig. 3) are perhaps the most valuable character for separating insectivore hairs from all other mammalian hairs with which they could be confused. The medullae are always simple and discontinuous throughout their entire length.

Overhair

Unlike the fur, the overhair of moles and shrews is quite varied and offers a number of good characters. Pelages of the several genera of moles (Talpidae) are easily distinguished by certain sets of overhair characters, but the hairs of shrew genera lack major diagnostic differences. The overhair distinctions that may be used in separating the genera of moles are set forth in key form below. Those of use in distinguishing the genera of shrews, on the other hand, are presented in discussion since they are not nearly so clear-cut and are therefore more difficult to define. The illustrations are intended to facilitate interpretation of the structural features and differences mentioned.

KEY FOR SEPARATION OF THE HAIRS OF MOLES AND SHREWS AND OF THOSE OF THE GENERA OF MOLES, BASED ON CHARACTERS OF TYPICAL OVERHAIRS

A. Overhair in cross section at the thickest part circular or elliptical in outline, with no deep emarginations; distal third usually expanded and clublike; basal two-thirds as in furhairs; length seldom less than 10 mm..... ...Moles (Talpidae) (Figs. 5–9).

b. Medulla at the largest part of the hair greater than the combined thickness of the cortex and cuticle on both sides..... Shrew Mole (*Neurotrichus*) (Fig. 5).

bb. Medulla less than the combined cortex and cuticle.

c. Medulla at the thickest part of the hair at least one-third of the total hair diameter; enlarged distal part of the hair about twice the diameter of the flexible basal part.

d. Cortical pigment absent or insufficient to darken the cortex; tips of hairs not attenuated to sharp fine points.... Hairy-tailed Mole (*Parascalops*) (Fig. 6).

dd. Cortex of back hairs highly pigmented and distinctly separated from the cuticle; tips of hairs sharply attenuated and slightly recurved..... Star-nosed Mole (*Condylura*) (Fig. 7).

cc. Medulla at the thickest part of the hair narrow, never more than one-third the total diameter, often absent; enlarged distal part at least three times the diameter of the flexible basal part.

e. Medulla of the clubbed portion either absent or fragmentary at the thickest part..... Common Mole (*Scalopus*) (Fig. 8).

ee. Medulla of club pres-

ent, distinct, and extending through most of the enlarged portion. Western Mole (*Scap-* . . . . . *anus*) (Fig. 9).

AA. Overhair in cross section at the thickest part more or less in the form of an H in outline, or with at least two deep emarginations; enlarged part of the hair constituting more than a third of the hair length and gradually tapering to the more flexible basal part; hairs usually less than 8 mm. long, except in the tundra shrew (*Sorex tundrensis*) which may have hairs 12 mm. in length; medulla, cuticle, and cortex relationship as in the shrew mole (*Neurotrichus*) (Fig. 5). . . . .Shrews (Soricidae) (Fig. 4).

IDENTIFICATION OF SHREW HAIRS

As stated previously, the hairs of the genera of shrews lack practical diagnostic characters. The illustrations in Figure 4 indicate how similar the hairs of the several genera are. There are minor differences noticeable under a microscope, however, which the worker learns only after comparing representative samples many times. If hairs have been identified as those of a shrew and further identification is attempted, it is suggested that the following characters be compared with those of known hair samples:

1. General aspect under a low-power dissecting microscope; this often aids in identification when more minute characters are confusing.

2. Hair diameters—the curly overhairs of *Blarina* appear consistently heavier than those of other genera.

3. Diameter of medulla in relation to that of the hair at the thickest part. In overhairs of *Blarina*, the medullae constrict noticeably basad of the greatest diameter. In other genera, the tapering is more gradual and the combined cortex-cuticle thickness is less.

4. Distribution and degree of pigmentation in the cortex. Pigment in hairs of *Cryptotis parva* sharply defines the margins of the cortex. Diagonal markings, also in the cortex (Fig. 4, B-6) have been observed in both *Blarina* and *Cryptotis* hairs, but not in those of other genera.

5. Character of the medulla in the enlarged part. The simple discontinuous type with flat-elongate medullary pigment masses is the common type in all genera, but in *Blarina* and to a lesser extent in *Sorex* the medulla shows some compoundedness.

6. Relation of size and shape of medullary pigment masses and air cells to each other, and to the area between air cells.

DESCRIPTIONS OF TYPICAL HAIRS OF THE VARIOUS GENERA OF MOLES

Shrew Mole (*Neurotrichus gibbsii*)

Length, about 10 mm.; expanded part of overhair variable in length, from less than 2 mm. to 2.5 mm.; tumescent area not sharply defined; tip gradually attenuated; medulla thicker than cortex and cuticle combined, simple discontinuous in curly overhairs, flat-elongate in thicker parts of the hairs, extending close to the tip; cortical pigment in a narrow band bordering medulla; cuticle usually distinct. Curly overhairs at the largest parts about twice the diameter of the furhairs.

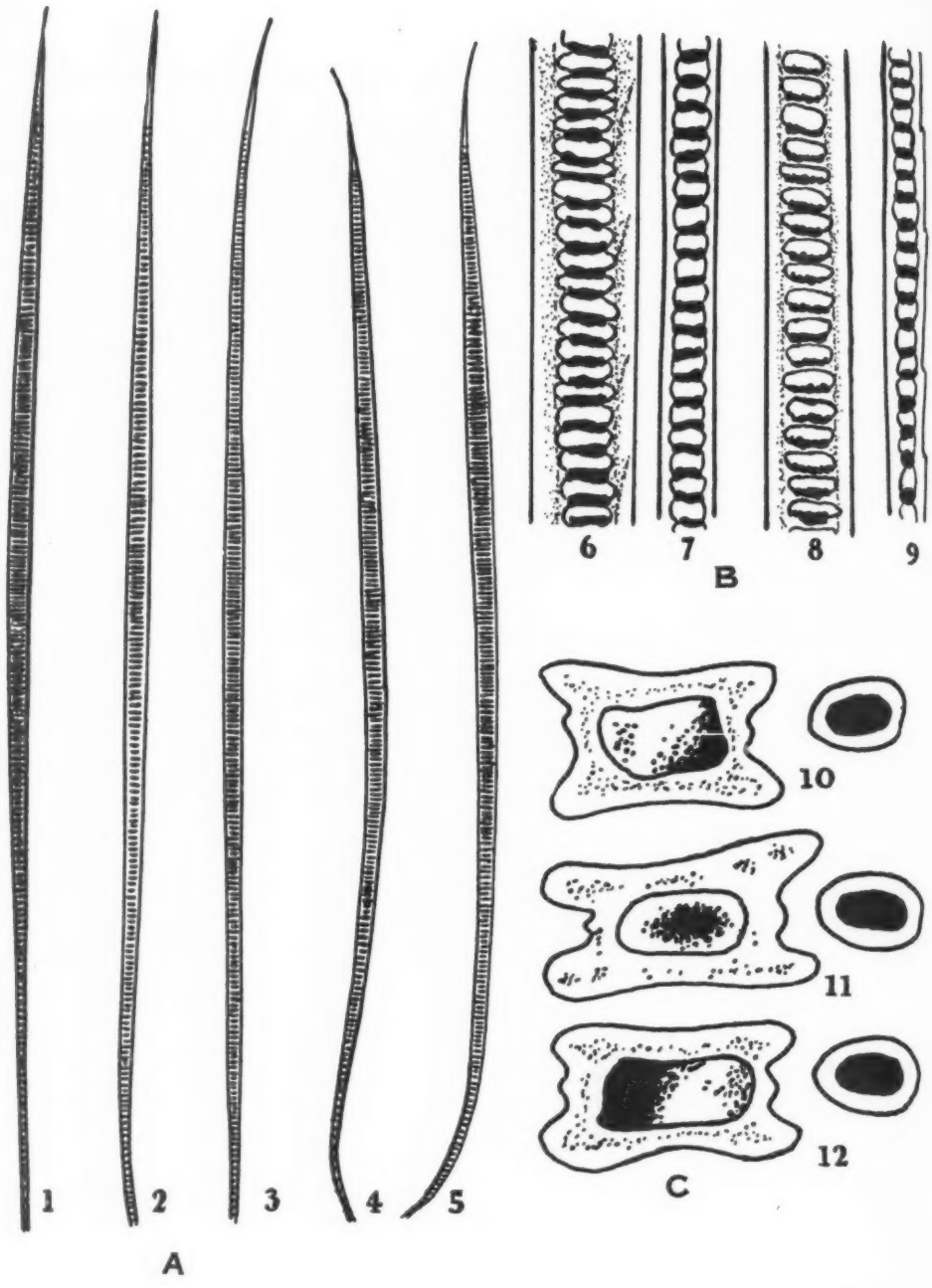

Fig. 4. (A) Terminal portions of curly overhairs of shrews (×40): 1, water shrew (*Sorex palustris*), 2, short-tailed shrew (*Blarina brevicauda*), 3, little shrew (*Cryptotis parva*), 4, pigmy shrew (*Microsorex hoyi*), 5, Crawford shrew (*Notiosorex crawfordi*). Approximately ×95.

(B) Longitudinal views of shrew overhairs at more and less slender parts; 6 and 7, short-tailed shrew; 8 and 9, Arctic shrew (*Sorex arcticus*). [Comparable views of hairs of other genera of shrews are very similar.] Approximately ×470.

(C) Cross sections of shrew overhairs at more and less slender parts (×500): 10, little shrew, (*Cryptotis parva*), 11, short-tailed shrew (*Blarina brevicauda*), 12, dusky shrew (*Sorex obscurus*). [Cross sections of hairs of other genera of shrews are almost identical with those figured.] Approximately ×1060.

Cross section through enlarged part roughly ovoid in outline. Heavier and longer hairs present and more abundant than curly overhairs, the medulla of these showing some compoundedness (Fig. 5).

Hairy-tailed Mole (*Parascalops breweri*)

Length, 10–11 mm.; enlarged portion (Fig. 6, A) averaging slightly under 2 mm. long; basal part as in other mole hairs; tip tapering very gradually to a rather blunt apex; cuticle clear; medulla always present, usually simple, but with some tendency toward compoundedness (Fig. 6, B), about half the hair diameter at the widest point; cortex only slightly pigmented with spheroid granules; medullary pigment masses

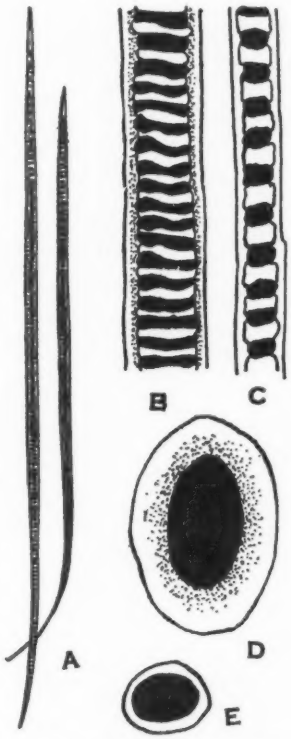

Fig. 5. Hair features of shrew mole (*Neurotrichus gibbsii*): (A) thicker part of curly overhairs, (B) longitudinal view of the largest part of an overhair showing type of medulla characteristic of hairs of this genus and indicating its relation to the cortex and cuticle, (C) basal part of overhair (Note the relative widths of B and C), (D) cross section of thick part of overhair, (E) cross section of slender part of overhair. Approximate magnifications: (A) ×57, (B and C) ×360, (D and E) ×800.

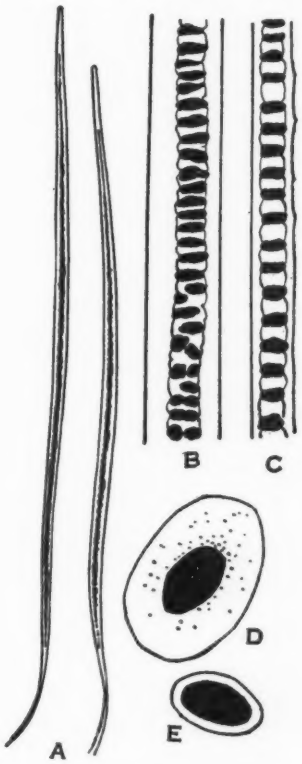

Fig. 6. Typical hair structure of hairy-tailed mole (*Parascalops breweri*); (A) longitudinal aspect of clubbed part of typical overhair [Note gradual tapering to a blunt tip], (B) part of the club showing character of medulla and its relation to hair width, (C) longitudinal section of an overhair near its base, (D) cross section of overhair through the largest part, (E) cross section of an overhair through the slender flexible part. Approximate magnifications: (A) ×57, (B and C) ×360, (D and E) ×800.

mostly wider than long, extending near to the hair tip. Enlarged part consistently more slender than in hairs of other moles. Larger hairs seldom more than twice as thick as the furhairs or the basal parts of the overhairs. Cross sections through club oval in outline.

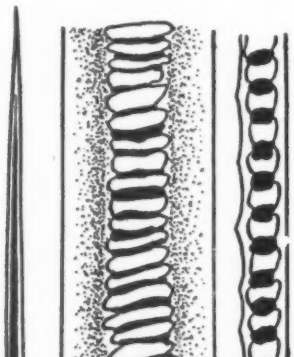

Fig. 7. Hair structure of star-nosed mole (*Condylura cristata*); (A) clubbed part of curly overhair, (B) enlarged view of part of the club showing flattened medullary pigment masses and air cells, (C) longitudinal view of part of an overhair near the base, (D) cross section of an overhair through the club, (E) cross section of overhair through basal part. Approximate magnifications: (A) ×57, (B and C) ×360, (D and E) ×800.

Star-nosed Mole (*Condylura cristata*)

Length about 12 mm.; clubbed part (Fig. 7, A) 2–3 mm. in length; furhair and basal part of curly overhair similar in appearance; tips rather abruptly attenuated, often with the apex recurved; medulla usually simple discontinuous, sometimes showing compoundedness, especially in very thick hairs, about

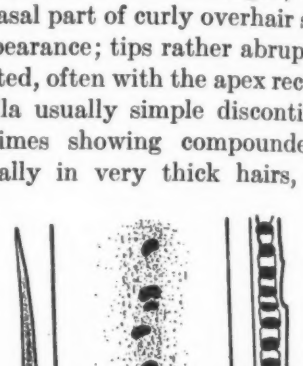

Fig. 8. Hair structures of common mole (*Scalopus*): (A) Clubbed part of typical curly overhair showing fragmental medulla ending basad of widest hair part, (B) longitudinal section of club showing medulla (*S. a. texanus*) slender in relation to hair width, (C) longitudinal section of an overhair toward its base, (D) cross section of curly overhair through the thickest part, (E) cross section of curly overhair through basal part. Approximate magnifications: (A) ×48, (B and C) ×300, (D) ×660, (E) ×600.

one-half the hair diameter as a maximum; cortical pigment granules globular, rather uniform in size, and arranged in linear series; masses of medullary pigment and the air cells elongate. Clubbed part of larger hairs about three times the diameter of furhairs or of the proximal part of the overhairs. Cross sections through clubbed part roughly circular in outline. Furhairs with clear recurved tips.

Common Mole (*Scalopus sp.*)

Length, 11–13 mm.; enlarged part (Fig. 8, A) about 2 mm. long; fine and wavy basally, similar to furhairs; tips tapering rather abruptly but not blunt; cuticle clear; medulla absent (*S. aquaticus*) or fragmental (*S. a. texanus*) in thickest part of the hair, less than a third of the diameter of the hair; pigmentation of cortex composed of roundish granules of varying sizes; medullary pigment of compact masses seldom twice as long as wide, in *S. aquaticus* ending basad of the thickest part of the hair. Hairs in cross section ellipsoidal, with or without a central medullary column.

Intermediate or transitional hairs are present in *Scalopus* pelages which resemble the overhairs of *Parascalops* in general aspect, but they differ in that the medullae are not prolonged into the major portion of the tip.

Western Mole (*Scapanus sp.*)

Length, 10–12 mm., clubbed part (Fig. 9, A) about 2 mm. long; tip robust, not attenuated, often worn to bluntness; cuticle thin and clear; medulla present, slender, usually less than, or about a third of, the hair diameter in the club, fragmental distally becoming simple discontinous (sometimes compound) proximally, extend-

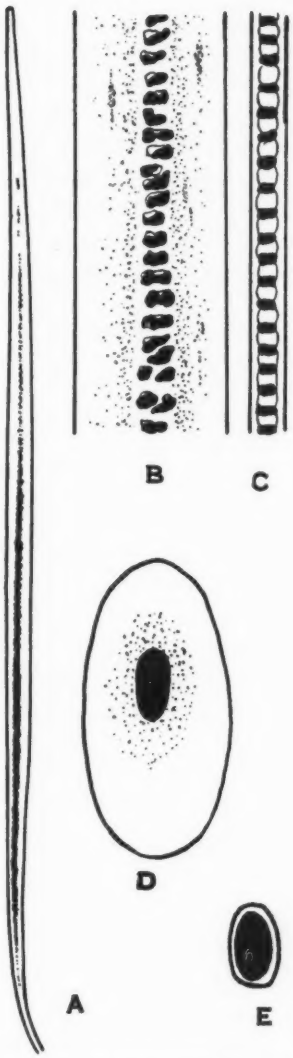

Fig. 9. Typical hair structures of western mole (*Scapanus*): (A) longitudinal view of club showing heavy tip and extent of medulla, (B) longitudinal section of club, (C) longitudinal proximal section, (D) cross section of an overhair through the club, (E) cross section of an overhair near the base. Approximate magnifications: (A) ×57, (B and C) ×360, (D and E) ×800.

ing through at least four-fifths of club; cortex often highly pigmented, with both diffuse and granular pigment; medullary pigment masses varying from globular to oblong, never consistently flat-elongate. Thicker clubs more than three times the diameter of fur hairs or proximal parts of overhairs. Cross sections through clubs are ellipsoidal, usually with prominent medullae.

Overhairs of *S. orarius* stronger, more heavily pigmented, with medullae heavier and extending closer to tips than in other species of *Scapanus*. Pigmentation is lightest in *S. latimanus*.

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A KEY TO HAIRS OF THE MAMMALS OF SOUTHERN MICHIGAN[1]

Harold A. Mathiak

Hair, common to all mammals, is important in biological studies. Food habit studies, involving fecal and pellet analyses, probably best illustrate the use to which knowledge of hairs can be put in wildlife management research. Hairs, identification of which is desirable, are found under many different circumstances. A wisp of hairs may be the only clue to the animals involved in cases of predation or in accidents of various types. Hairs challenging determination may be found also in sprung traps or about the entrances of dens.

There is little information sufficiently specific to enable a beginner to identify hairs of even the common mammals. The practice now prevailing is the laborious, hit-or-miss process of comparing unknown with known samples. It is hoped that the key here presented will make it possible for the beginner to identify many hairs with less resort to the comparison method. Using some of the specific characters described, it may be possible to recognize certain hairs without use of the key.

Only the hairs of the more common mammals of southern Michigan (south of township line 16) are treated in this key.[2] Distinguishing criteria given in the key are not necessarily valid for related species although it is anticipated that the key may prove of some value for identifying hairs of mammals of adjoining areas. Domestic mammals have been included, but only sufficiently to guard against confusion of their hairs with those of wild forms. Some species have been grouped together even though their hairs are probably distinct enough to permit specific identification. Others have been grouped from necessity because of the close resemblance between their hairs.

There may be three or more types of hairs represented in considerable numbers on an individual mammal. The hairs within each type vary chiefly with the season of the year and with the age of the mammal. The young are at first provided with a fine, fluffy coat of hairs. The writer had no opportunity to study these hairs so that it is not known whether or not they can be identified by means of the key. At the age of several weeks, hairs appear which, although small at first, are similar to those of adults.

Gunn (5, 6), after intensive studies of the differences between prime and unprime pelts, states, "the conclusion may be drawn that the differences represent merely different phases in the life cycle of the hair." Hadwen (7, 8), in studying the color changes in snow-

[1] A thesis submitted in partial fulfillment of the requirements for the degree of Master of Forestry at the School of Forestry and Conservation, University of Michigan, in June, 1938. Grateful acknowledgment is made to H. M. Wight under whose direction this work was done.

[2] The writer has studied only the hairs of the mammals mentioned in the key. Generalizations are mostly concerned with this limited group and can hardly be expected to hold true for all cases in areas with a different fauna.

shoe hares, found that the whitening of the hairs was due to a blanching of the pigments of the hair shaft and not to the growth of an entirely new coat of white hairs. Mature hairs degenerate, but these frayed hairs, which he called kempy fibers, are never present to the exclusion of the easily recognized sound hairs.

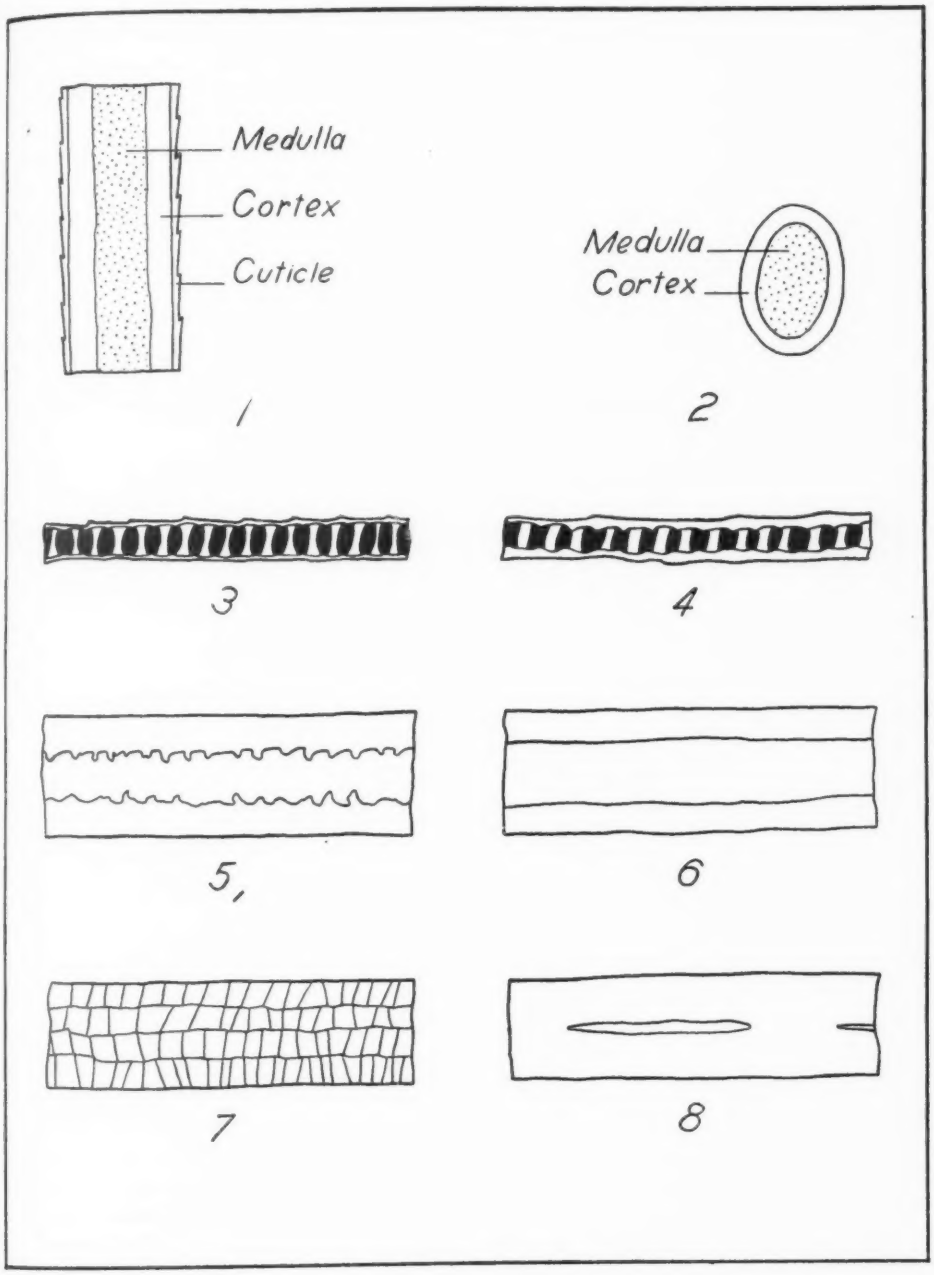
Other writers, Allen (1) and Grange (4) contend that the whitening of the hare is due to the growth of a new coat of white hairs. Whatever the case may be, the changes in a hair becoming prime, or white as in the variable mammals, is essentially a change in pigmentation, the gross structure not being materially altered. Pigmentation has not been made a major feature of the key owing to a further reason, namely diversity of pigment granule arrangement in the hairs of certain species. Pigment may be uniformly distributed throughout the cortex, concentrated in longitudinal bands, or lacking entirely. There is also much variation in the size and color of the pigment granules. A third factor rendering dependence on pigment undesirable is the deterioration it sometimes undergoes when subjected to weathering or to the action of digestive juices.

The color of the back, sides, and belly of mammals may be identical, or as is often the case, lighter or differently colored ventrally, but the hairs are usually similar in structure. Most hair analyses will be concerned with body hairs for the reason that they constitute such a large percentage of the total number of hairs. Head, leg, or tail hairs may be either of the same, or of totally different, structure. Head hairs are sometimes considerably flattened and of greater diameter than any of the body hairs.

HAIR STRUCTURE

Description and classification of the variations in hair structure and form are taken with certain modifications from the papers of Dr. L. A. Hausman (10, 11, 12). The parts of a hair are the root or bulbous portion situated beneath the surface of the skin and the shaft or the portion extending above the surface. The shaft of a typical hair is composed of three elements, the medulla, cortex, and cuticle (Figs. 1, 2). The medulla is a central core or pith including shrunken cells of irregular shape, air spaces, and pigments. Three types of medullae are referred to in the key. The discontinous medulla is one which has isolated chambers that lie in a single row. This type of medulla is most commonly found in fur hairs and may occupy a larger (cortex relatively thin as seen in Fig. 3), or smaller, proportion of the shaft (cortex relatively thick as seen in Fig. 4). Masses of melanin or pigment granules between the medullary chambers may cause the medulla to appear continuous at first glance (Fig. 3).

The continuous medulla is characteristic of guard hairs although it is found also in other types. A few variations of the continuous medulla are shown in Figures 5–7. Figure 5 illustrates in outline an erose continuous medulla or one of irregular construction and Figure 6 a smooth medulla of more regular form. The erose medulla is well exemplified in the larger hairs of many rodents. The medulla is fragmental when it consists of unconnected sections of varying length (Fig. 8). Hairs of some



Figs. 1–8. 1, Diagram of a longitudinal section of a hair shaft; 2, diagram of a cross section of a hair. Usually the cuticle is too thin to be seen in cross section; 3, discontinuous medulla of a furhair with a relatively thin cortex; 4, discontinuous medulla of a furhair having a relatively thick cortex; 5, outline of the erose continuous medulla of a muskrat guard hair; 6, outline of a smooth continuous medulla; 7, intermediate hair of rabbit, with a chambered medulla and a very thin cortex; 8, fragmental medulla of a human hair.

species commonly have a continuous medulla in part of the shaft and a fragmental medulla in the remainder. An erose continuous medulla frequently becomes discontinuous for a short distance before disappearing at the tip of the hair.

Guard or intermediate hairs of the rodents may have a compound or alternated medulla, a type which is most commonly found in this order of mammals. Two variations of the compound medulla are shown in Figure 9. Hairs having an erose continuous medulla may be so pigmented with alternating masses of melanin that they somewhat resemble hairs with compound medullae. To facilitate future reference to these types of compound and apparently compound medullae, they are called the "rodent base." The rodent base is most commonly seen in the basal portion of hairs, its appearance varying with the character of the pigment granules in the cortex and medulla. Upon acquaintance it can be recognized even in hairs with a heavily pigmented cortex or those in which the melanin of the medulla is lacking. The rodent base may be seen also in the guard hairs of the rabbits, but only very rarely in hairs of other groups of mammals.

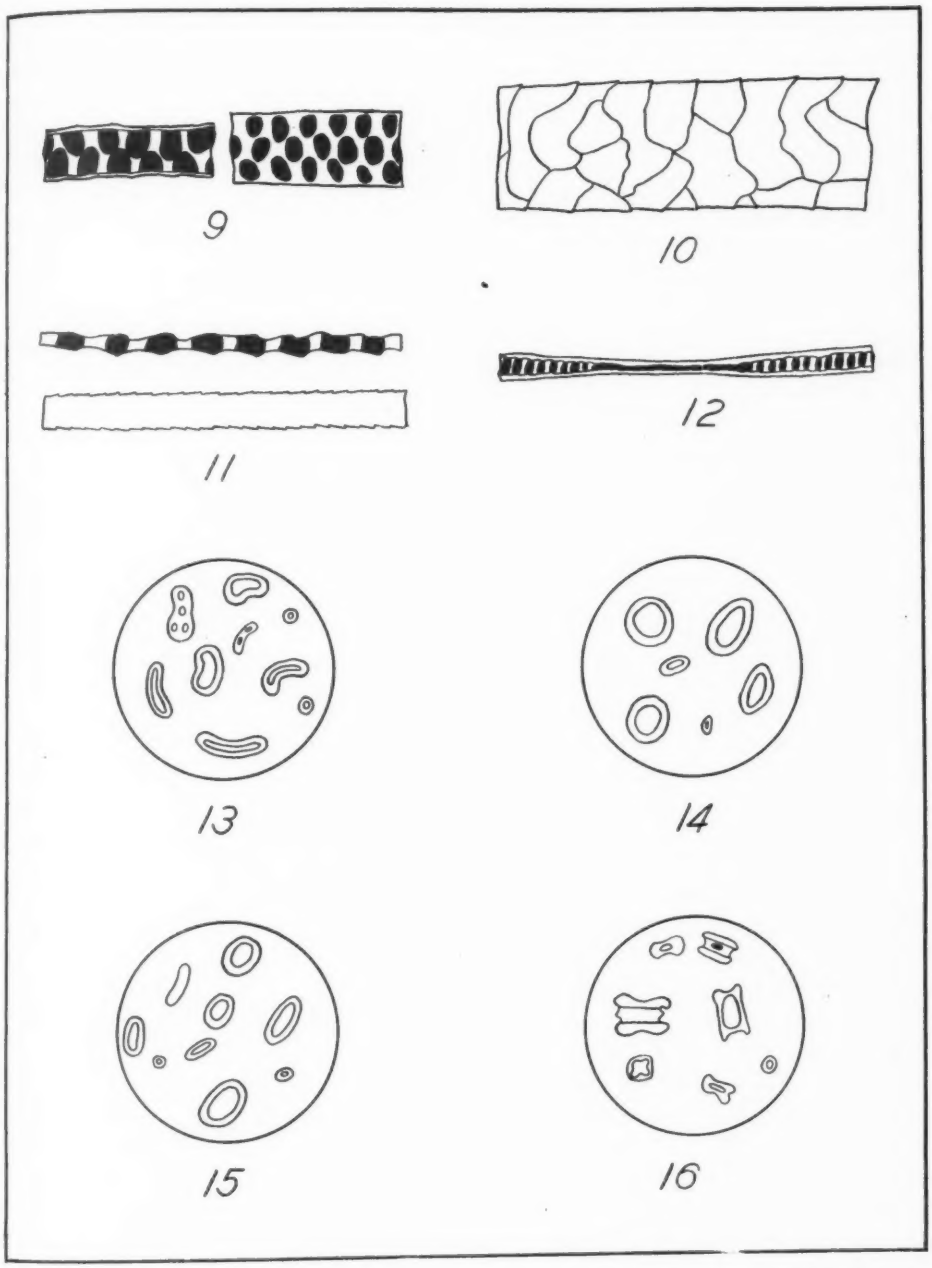
The cortex is a hyaline layer of fusiform cells surrounding the medulla. Its cells are transparent and partially fused together so that they cannot readily be seen unless treated with acids or alkalies. The cortex contains air spaces (fusi) and pigments that are partially responsible for the characteristic colors of hairs. The pigments may be either in the cells themselves or in the spaces between the cells. Pigments are diffuse or more commonly in the form of granules. Usually there is a little diffuse pigment associated with pigment granules (Boyd, 2).

A single layer of flattened, transparent cells forms the cuticle or outermost layer of the shaft. It is reticulate with scales of two types, imbricate scales (Fig. 10) and coronal scales (Fig. 11). An imbricate scale extends only part way, while a single coronal scale extends completely, around the shaft.

HAIR TYPES

Hairs can roughly be divided into four groups: Specialized hairs, guard hairs, furhairs, and hairs intermediate between guard and furhairs. Many oddities in specialized hairs are shown by mammals throughout the world. The quills of the porcupine (found in northern Michigan) are markedly unlike any hairs of the mammals of southern Michigan.

Tactile hairs, vibrissae, or "whiskers," possessed by practically all mammals, are found on the head or sometimes on the forelegs. They are markedly different from all other types of hairs. They are the only hairs which taper all the way from the base to the tip. All other hairs (excluding those with nodes and internodes) taper toward both the base and the tip. In tactile hairs the medulla is often lacking; when present, it is never conspicuous. Typically it is continuous at the base, but soon becomes fragmental and disappears. Vibrissae are characterized also by an extremely long drawnout tip not paralleled in other hairs of corresponding diameter. Cross sections of tactile hairs are circular or nearly so. The cortex generally contains dark pig-



Figs. 9–16. 9, Two variations of the compound medulla or "rodent base"; 10, imbricate scales of a fox hair; 11, bat hairs one with heavily pigmented coronal scales; 12, an internode and parts of two nodes with a continuous medulla; 13, cross sections of guard hairs of house mice, deer mice, field mice, and young brown rats; 14, cross sections of jumping-mouse hairs; 15, cross sections of flying-squirrel hairs; 16, cross sections of shrew hairs.

ment granules which may be so numerous as to conceal the medulla.

There is considerable range in the size of tactile hairs from a single individual, the largest hairs often being longer and larger in diameter than any of the body hairs. Large tactile hairs are conspicuous by their size in pellets and feces containing quantities of hair of small mammals. Tactile hairs are readily recognized as such but, being very similar in structure in different species, they are of almost no value for identification purposes. These hairs have not been included in the key, therefore, or taken into account in the following discussion.

Guard Hairs. Excluding the vibrissae, then, the guard or protective hairs are the largest in both diameter and length. The medulla of guard hairs is generally continuous. A typical form of guard hair is one which is fusiform in shape or of largest diameter near the mid-region and tapering toward both ends. Cross sections of guard hairs may have a variety of shapes never found in those of fur. The scales are often closely appressed, giving the guard hairs a high luster. Short guard hairs may exhibit much, while long guard hairs sometimes show little, taper.

Furhairs. Furhairs are the finest hairs of a pelt and constitute what is known as the underfur. They often have discontinuous medullae and prominent scales but are never enlarged distally. Many furhairs have nodes and internodes, an internode being a constriction of the shaft (Fig. 12), while a node is that portion of the shaft lying between two internodes. Pigmentation, except at the tip, is generally confined to the medulla; some species, however, have pigment in the cortex of the hair. Except near internodes and extremities, fur hairs have very little taper, the sides of the hair appearing parallel under the microscope.

Intermediate Hairs. These intergrade between guard and furhairs. A common type is one enlarged distally while the basal part is finer and somewhat similar to that of furhairs in constitution.

Hair structure may or may not indicate taxonomic relationships. In the genus *Mustela*, for example, hairs of the various species appear identical except in size. In other instances, hairs of distantly related species appear almost identical. Thus the long dark guard hairs of the brown rat, *Rattus norvegicus*, appear very similar to some of the leg hairs of the skunk, *Mephitis nigra*, excepting that the scales at the base of the hair are transverse in *Mephitis* and longitudinal in *Rattus*.

Size is of some value in hair identification. For each species there is a maximum diameter and length beyond which it is unlikely that larger hairs will be found. Thus given a hair of a certain length, mammals never having hairs that long are eliminated from further consideration. For instance, a hair 40 mm. long belonging to the genus *Mustela*, could not be referred to the least weasel, *M. rixosa allegheniensis*, because that animal never has hairs so long. On the other hand, a hair only 10 mm. long could have come from the back of a least weasel or the head or legs of a mink or New York weasel.

The key forming the bulk of this paper is based almost entirely on guard and intermediate hairs, as being more characteristic and easier to handle. These coarser hairs are not injured as

much as those of the fur by the action of digestive juices, but even guard hairs may be broken by mechanical forces. Furhairs, having a thinner cortex, are often severely macerated and discolored in feces and pellets, the medulla frequently being totally blackened. Occasionally a sample of furhairs is found without any guard hairs being present, but if abundant some guard hairs probably can be found.

TECHNIQUE

Certain equipment is needed for the efficient microscopical examination of hairs. The microscope should be provided with an ocular micrometer, Abbe condenser, and daylight lamp. A mechanical stage is almost a necessity for proper manipulation of the hair while under observation, for it is desirable that any portion of a hair can be brought into the microscopic field quickly and easily. Measurements of diameter in micra (μ) are taken with the ocular micrometer. One micron is equal to 1/1,000 of a millimeter. Details as to the use of the microscope and its accessories can be found in any of the textbooks of micrology or microtechnique.

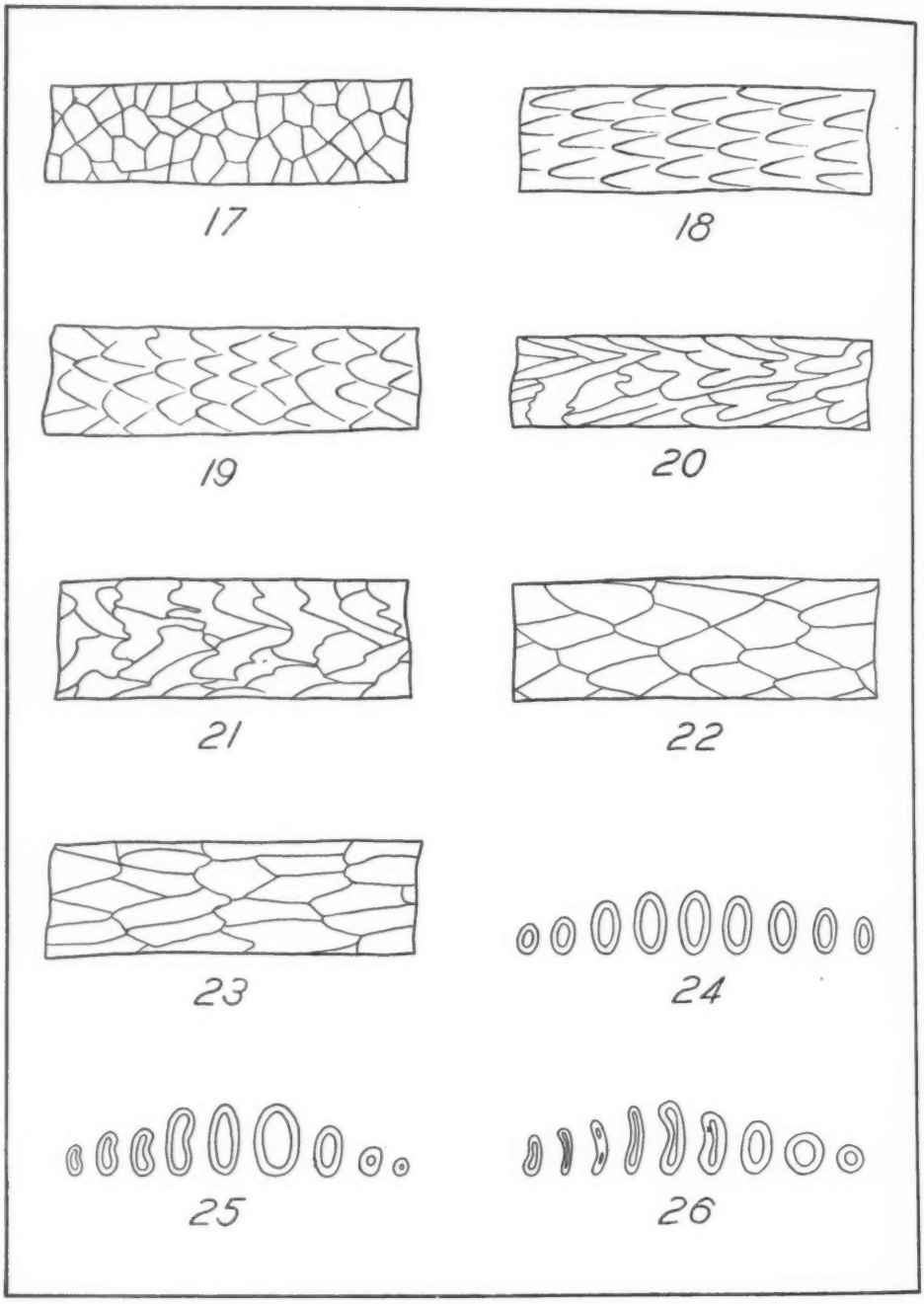
Except when very dirty, hairs can be mounted directly in an essential oil (oil of cloves, oil of bergamot, etc.) or in xylene, for longitudinal examination. These reagents make the elements of the hair more clearly visible under the microscope. Xylene is a good medium to use, for after the hairs have been examined, the slide and cover glass can be wiped clean with a dry cloth, thus eliminating the task of washing the slides. The work room should be well ventilated, for xylene evaporates readily and has a penetrating, slightly disagreeable odor. Only transmitted light need be used for the examination of hairs and their cross sections. Dirty hairs can be washed in a volatile, grease-dissolving reagent such as alcohol, ether, or carbon tetrachloride.

Cross-sectioning Hairs

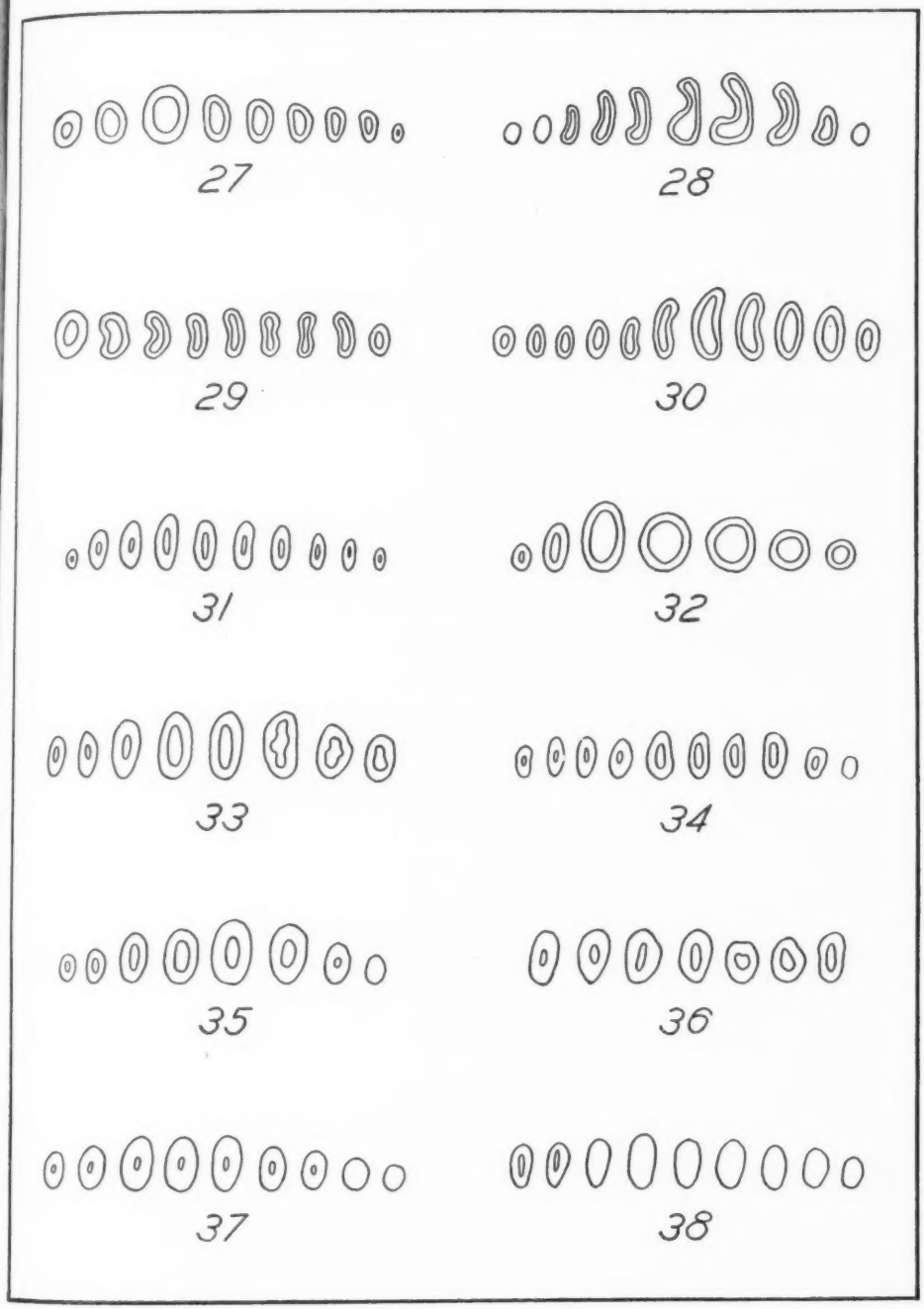
To use the key successfully, it is frequently necessary that the character of cross sections be known, either at a stated region of the hair or serially for the entire length of the hair. The cross sections can be made by the method previously reported by the writer.[3] The serial drawings of cross sections (Figs. 24–38) are for individual hairs while the composite illustrations (Figs. 13–16) represent cross sections of groups of hairs. The cross sections show the general shape and proportions of the cortex and medulla rather than an exact match for any hair that might be sectioned.

The serial sections have usually been taken at uniform, but sometimes at notable, distances apart. When two adjacent cross sections vary widely in shape, therefore, intergradations between the two shapes must have existed. All drawings progress from the base of the hair (to the left) toward the tip (to the right). Cross sections of short hairs should be taken at smaller intervals than in long hairs as their shapes may change much more quickly in a given length. Identification is facilitated by performing the various operations in a standard, systematic order.

[3] Mathiak, H. A. A Rapid Method of Cross-Sectioning Mammalian Hairs. JOURN. WILDLIFE MANAGEMENT, 2(3), July 1938, pp. 162–164.



Figs. 17–26. 17, Irregularly polygonal chambers in the medulla of a deer hair; 18, long-pointed scales such as are found on some hairs of the genus *Mustela;* 19, sharp-pointed scales found in a lesser number of hairs of the genus *Mustela;* 20, scales of certain hairs of squirrels; 21, a variation of the scales in squirrel hair; 22, 23, scales as found on hairs of the brown rat, fox, and coyote; 24, mink; serial cross sections: 25, squirrel; 26, brown rat. Figs. 24–26 show serial cross sections of individual hairs. The base of the hair is to the left and the tip to the right.



Figs. 27–38. 27, Coyote; 28, 29, ground squirrel, *Citellus;* 30, woodchuck; 31, muskrat; 32, chipmunk; 33, white guard hair of opossum; 34, intermediate hair of opossum; 35, raccoon; 36, badger; 37, small head hair of raccoon; 38, small leg hair of badger. Figs. 27–38 show serial cross sections of individual hairs. The base of the hair is to the left and the tip to the right.

When imbedding a hair to obtain serial cross sections, the base of the hair is conveniently grasped with a fine-pointed forceps and the hair laid on the celluloid with its base at the right end of the stick of balsa wood. After the sections have been sliced, they can be placed on the slide in serial order and examined from the base to the tip of the hair, comparing them with the figures when necessary.

Usually the basal and distal ends of a hair can be determined with the naked eye or by the aid of a hand lens. Most of the hairs with noticeable taper are of maximum diameter somewhere in the distal half of the hair although tail hairs are sometimes a little coarser in the basal half. Many times the basal end of the hair is conspicuously heavier than the tip which ends in a fine point. Some hairs are of equal fineness at base and tip. In such cases the microscope must be resorted to; the extreme distal end of a hair can be told by the manner in which the scales overlap, the distal end of an individual scale always overlapping the basal end of the adjacent scale. The basal end of the hair either terminates in a broken surface or in a bulbous enlargement, the root.

Scale Examination

Saxinger and Herzog, both referred to by Hardy (9), developed a quick method for determining the form of cuticular scales. Their method is to place a thin coating of a plastic material on a slide, press the hairs into the plastic substance, and allow it to harden. The hairs are then removed and the negative impression of the scales examined under the microscope. The celluloid solution used in cross-sectioning serves well as the plastic material. This operation is not difficult to perform after a little experimentation with the viscosity of solution used and choice of the time to lay the hairs on the celluloid. It does not matter how hard the celluloid dries since only one side of the hair is in contact with it, and the hair can be removed without difficulty.

Hardy (9) and Manby (13, 14) present modifications of this method by which positive impressions of the scales can be studied. The simplest method is to attach the ends of the hair to the slide with the shaft flat against it. A drop of celluloid solution is placed along the hair and allowed to dry. The hair is then torn out, the slide inverted, and the impression studied under the microscope. To prevent breaking, the hairs should be pulled out of the celluloid before it becomes too hard.

These methods were developed principally to facilitate photography of the scales, which requires that the images be sharply defined. For the purpose of the key, it is not essential to obtain clear-cut images. The hairs can be laid in the celluloid without regard to the depth to which they are immersed. If cover slips are used instead of slides the high power of the microscope can be used to better advantage. It is not necessary to fasten the hairs to the cover slip or have the lower surface of the hair in contact with the glass. Only in a few genera is the scale form of guard hairs sufficiently characteristic to identify the hair with certainty. In these cases it is always knowledge as to the scale form in the basal portion of the hair that is desired. The scales at varying distances along any one

guard hair may show a great diversity of form, but those at corresponding regions of hairs of the same type are fairly uniform in appearance. In the species that can be identified by scale structure, it will be found that some hairs have the characteristic scale form for only a short distance near the base. When ascertaining scale structure, therefore, five or more hairs should be imbedded at one time to insure a reliable representation.

KEY

The key, it will be noted, consists of a key proper and interspersed notes. The key points out the most distinctive characteristics and its aim is to keep the amount of time required to identify a hair to a minimum. The notes consist of supplemental information to help verify identifications. Furhairs are briefly described as they appear in samples from the middle of the back, no account being taken of the variations in different parts of the body. Moderate experience with the key should permit the user in many instances to ignore the notes.

In proceeding to identify a hair, longitudinal examination should first be tried. It is an easy matter to mount several hairs of each type present in the sample, and some kinds can thus be identified without further examination. Scale form may next be determined on the basal half of some of the larger hairs. When sectioning is required, a good general rule is to section a hair of the largest average size represented in the sample. Cross-sectioning requires time so that for the coarser hairs treated in Division II only one hair usually is sectioned.

The most effective way to become familiar with the key is to work first with known samples, comparing their scales, medullae, and cross sections with the descriptions and drawings. Certain features, such as the scales on hairs in the genus *Mustela*, need be seen but once to be remembered. Familiarity with mammal pelages often is helpful. Short, distinctly banded hairs of a ground squirrel would hardly be considered as belonging to a skunk nor would a sample of white hairs be mistaken for those of a muskrat.

It seemed desirable to divide the key into two Divisions. Size distinctions between hairs in the two groups is one factor favoring their separation, Division I relating only to mammals with fine, relatively short hairs. There is also a similarity in the manner of occurrence in samples (as in feces and pellets), hairs of mammals represented in Division I practically always being found in considerable numbers. Most of the species are rather small and are generally ingested entire when taken as food; thus there is usually an abundance of hairs in the sample.

A Hairs finer, not more than 25 mm. long and 110μ in diameter, being usually less than 15 mm. long and 60μ thick. There are generally more than 200 hairs per sample..... .....Division I

AA Hairs coarser, the largest hairs more than 25 mm. long or 110μ in diameter; if less than 25 mm. long or 110μ thick, there are usually less than 200 hairs per sample..... .....Division II

DIVISION I

This division includes hairs of the

moles, shrews, bats, flying squirrels, mice, and very young brown rats. All are short and fine and usually form a pelage having a silky feeling and appearance. The hairs often have nodes and internodes. The furhairs are more numerous than the protective hairs, and their medullae, when present, are discontinuous. Providing hairs from only one species are included in the sample, those of Division I are easier to identify than the hairs of many of the larger mammals. When the hairs of several species are mixed together, numerous xylene mounts and cross sections are required in order to make certain that all kinds present are noted.

Samples of the hairs of these small mammals are most often found in feces and pellets and usually contain several hundred hairs. The key is based on the assumption that a goodly number of hairs are available. Cross sections are made not of a single hair but of a representative cluster of the largest hairs in the sample. The hairs are imbedded as a group and as many slices as necessary are made to provide cross sections through the largest hairs at their greatest diameters. Since it is necessary to determine the shape of only the largest cross sections, serial illustrations are not given.

Hairs of the mammals of Division I, especially those considered as buffer species, are frequent subjects in food habits studies. Pellets of the larger hawks and owls usually contain the remains of more than one mammal and since the skulls are ejected with the hairs, it is probably easier to base identifications on the skulls when a larger number of pellets are to be analyzed. Skulls give information as to numbers while the hairs can provide data only as to the species represented. It is difficult to detect all of a variety of species when the hairs are matted together, particularly those with circular or elliptical cross sections since practically all species have at least a few hairs of these shapes. Skulls also make it easier to determine species in a group such as the mice in which hairs of the various species are very similar in structure.

A different problem is presented by feces from which skulls are usually absent and hairs must of necessity be used as a basis for identification. Some mammalian feces contain hairs of the animal depositing them; thus skunk feces may include a few skunk hairs, most often from the legs.

1 Larger hairs often having the rodent base, (Fig. 9).....2

1′ Larger hairs without the rodent base. Very rarely the medulla may be so constructed for a short distance as to somewhat resemble the rodent base.....4

2 Cross sections of many of the larger hairs flattened or concave on one side as shown in Figure 13.

Deer mouse, *Peromyscus* sp.

Cooper's lemming vole, *Synaptomys c. cooperi.*

Field mouse, *Microtus* sp.

House mouse, *Mus musculus.*

Young brown rat, *Rattus norvegicus.*

NOTES. Hairs fine, maximum diameter about 80μ, usually less than 18 mm. long. Hairs do not have distinct

bands of colors. Furhairs may have nodes and internodes. Medulla at internodes sometimes continuous, but mostly discontinuous.

2′ Cross sections of the larger hairs not as in Figure 13, usually inflated, oval, or circular in outline.....3

3 Furhairs with nodes and internodes. Cross sections of guard hairs always inflated, elliptical to circular as shown in Figure 14. Hairs usually less than 12 mm. in length and 110μ in diameter.

Meadow jumping mouse, *Zapus h. hudsonius.*

3′ All hairs without nodes and internodes. Outline of cross sections of guard hairs inflated or very slightly concave on one side as indicated in Figure 15. The larger and more rounded of the cross sections shown are of tail hairs. Largest hairs about 70μ in diameter and 25 mm. in length. Hairs very soft and wavy.

Eastern flying squirrel, *Glaucomys v. volans.*

4 Hairs without nodes and internodes, usually less than 20μ in diameter. Medulla usually lacking. Scales mostly coronal, sometimes thickened and very prominent on some hairs (Fig. 11).

Little brown bat, *Myotis l. lucifugus.*

Silver-haired bat, *Lasionycteris noctivagans.*

Large brown bat, *Eptesicus f. fuscus.*

Red bat, *Nycteris b. borealis.*

4′ Many of the hairs with nodes and internodes; practically all with a discontinuous medulla.....5

5 Hairs very fine, with the distal node of some greatly enlarged (as seen under high power). Enlarged portion lightly pigmented with brown granules, the medulla fragmental or lacking. Rarely the medulla is discontinuous in the basal half of the enlarged node.

Prairie mole, *Scalopus aquaticus machrinus.*

NOTES. Distal node up to 75μ in diameter. Furhairs and unenlarged part of guard hairs have a discontinuous medulla and relatively thin cortex.

5′ Hairs with distal node not enlarged and with the medulla fragmental or lacking in the enlarged portion....6

6 Largest cross sections shaped as in Figure 16.

Short-tailed shrew, *Blarina brevicauda talpoides.*

Least shrew, *Cryptotis parva.*

Masked shrew, *Sorex c. cinereus.*

NOTES. Hairs usually less than 55μ in diameter and 10 mm. in length. Medulla discontinuous except at the internodes where it commonly becomes continuous.

6′ Largest cross sections circular, never as in Figure 16.

Star-nosed mole, *Condylura cristata.*

DIVISION II

This division is concerned with the hairs of the larger mammals. A majority of the wild species have hairs with

features distinct enough to permit generic or specific classification. In contrast, the hairs of the domestic mammals are more difficult to describe and identify, both because of the multiplicity of breeds and because the hairs themselves lack distinctive characteristics.

A few hairs of the wild mammals are of such character that they cannot be included in the key, as the smaller head and leg hairs and the tail hairs of certain species. In these the medulla is often much reduced in size and the cross sections tend to assume circular or otherwise bilaterally symmetrical shapes. Unless the scales are distinctive, such hairs are very difficult to identify. All hairs which cannot be described so as to be identified with reasonable certainty by the key are assigned to a miscellaneous group at the end. The characters given in the key in combination with those in the more detailed notes should prevent any hairs belonging to the miscellaneous group from being placed in any bracket of the key.

7 Hairs fine and exceedingly curly, usually found in a tightly matted mass. Medulla usually lacking. Scales not conspicuously thickened. Hairs of approximately uniform diameter, without noticeable taper.

Sheep, *Ovis aries.*

7′ Hairs, if fine, not exceedingly curly; otherwise hairs coarse or with a well-developed medulla.....8

8 Medulla of some hairs in longitudinal view appearing to be made up of squares and rectangles, mostly in continuous longitudinal rows (Fig. 7). In other hairs the cubical cells can be seen lying in longitudinal rows.

Snowshoe hare, *Lepus a. americanus.*

Cottontail rabbit, *Sylvilagus floridanus mearnsii.*

NOTES. Guard hairs do not have these rows of cells, but they are much less numerous than the intermediate hairs so that it would be impossible to obtain a sample consisting only of guard hairs. Both guard and intermediate hairs have cross sections showing concavities.

8′ Medulla in longitudinal view not appearing to be made up of squares and rectangles or longitudinal rows of cubical cells.....9

9 Medulla composed of distinct chambers, irregularly polygonal in shape as indicated in Figure 17. In many hairs the cortex is very thin, the medulla occupying almost the entire shaft.

White-tailed deer, *Odocoileus virginianus borealis.*

NOTES. Cross sections circular to oval. In head and leg hairs the cortex may be thicker, but the medullary chambers are of the distinctive character illustrated. Hairs may be over 300μ in diameter.

9′ Medulla otherwise, or cortex never extremely thin with the medulla occupying almost the entire shaft.....10

10 Scales of basal portion of guard hairs acuminate distally (Fig. 18). In some hairs the scales may be shorter, but a few at least have very straight distal edges coming to sharp point (Fig. 19). Cross sections are usually elliptical as shown in Figure 24.

Mink, *Mustela vison mink.*

New York weasel, *M. n. noveboracensis.*

Least weasel, *M. rixosa allegheniensis.*

NOTES. Hairs never banded, usually brown or white. Brown hairs with pigment granules very evenly distributed throughout the cortex. Tail hairs may be circular in cross section and without the distinctive scales.

10′ Basal portion of guard hairs without acuminate or acute scales as shown in Figures 18 and 19. Hairs may be banded or have cross sections of irregular shape.....11

11 Scales at the base of guard and intermediate hairs irregular, as shown in Figures 20 and 21, for a distance of at least 200μ along the shafts. Basal portion of many intermediate hairs with cross sections concave on one side as in Figure 25. The largest guard hairs have cross sections elliptical in outline.

Red squirrel, *Sciurus hudsonicus loquax.*

Gray squirrel, *S. carolinensis leucotis.*

Fox squirrel, *S. niger rufiventer.*

11′ Scales at the base of guard and intermediate hairs otherwise.[4] 12

12 Scales on basal portion of guard or intermediate hairs similar to those shown in Figures 22 and 23.....13

12′ Scales on basal portion of guard and intermediate hairs otherwise.....14

13 Some hairs with the rodent base. Guard hairs of two types; the darkly pigmented hairs have circular cross sections while the lighter pigmented hairs have in part flattened cross sections as shown in Figure 26. Furhairs less than 20 mm. long, with one prominent internode.

Brown rat, *Rattus norvegicus.*

13′ Hairs without the rodent base. Furhairs wavy, usually more than 30 mm. long, and without internodes. Cross sections of guard hairs, circular, oblong, or sometimes flattened on one side as shown in Figure 27.

Fox, *Vulpes fulva.*

Coyote, *Canis latrans.*

14 Cross sections concave on one side for practically the entire length of the hair, as in Figures 28 and 29.

Ground squirrel, *Citellus t. tridecemlineatus.*

NOTES. Furhairs commonly without a medulla;

[4] A few hairs of the chipmunk have scales somewhat similar to those shown in Figures 20 and 21, but they usually do not occur to a distance of 200μ along the shaft and the cross sections are never concave on one side.

some may have a fragmental or discontinuous medulla for a short distance near the tip of the hair. Cortex of furhairs with numerous pigment granules.

14′ Cross sections not concave on one side for practically the entire length of the hair. 15

15 Cross sections of basal and distal portions of guard hairs elliptical, those of the mid-shaft concave on one side (Fig. 30). In other hairs, the basal portion has cross sections concave on one side while in the distal half they are elliptical. Many of the guard hairs have a white band about 5 mm. long near the tip of the hair with the extreme apex containing pigment granules. Sometimes these can be seen only with the aid of the microscope. Such white-zoned hairs with pigment in the extreme tip are characteristic of the woodchuck and occur also in the tail of the ground squirrel; the ground squirrel hairs, however, have cross sections concave on one side for most of their length.

Southern woodchuck, *Marmota m. monax.*
Rufescent woodchuck, *M. monax rufescens.*

NOTES. The cortex of the furhairs is relatively thick and contains numerous pigment granules. Some belly and leg hairs have a very clear, diffuse-reddish pigmentation which is characteristic; the cross sections of these hairs are rounded in outline.

15′ Cross sections of guard hairs not concave on one side in the basal or middle parts of the hairs.....16

16 Cross sections narrowly elliptical (Fig. 31). Medulla erose and slender, usually less than ⅓ as thick as the hair (Fig. 5). Cortex of guard hairs has numerous pigment granules arranged in longitudinal streaks. In paler hairs numerous irregular chambers can be seen in the medulla.

Muskrat, *Ondatra zibethica.*

NOTES. Surface of hairs smooth and with a high luster. Hairs usually without distinct bands of color. Furhairs with a discontinuous medulla.

16′ Cross sections otherwise; guard hairs without a slender, erose medulla...17

17 Many hairs with the rodent base. Hairs never more than 20 mm. long. Cross sections of largest guard hairs unusually regular, being elliptical in the basal half and circular in the distal half (Fig. 32).

Chipmunk, *Tamias striatus lysteri.*

NOTES. Cortex of many furhairs relatively thin and without pigment granules but containing a few scattered air chambers. Tail hairs are circular or nearly so in cross section. Tips of some fur and intermediate hairs have a diffuse pigmentation.

17′ Larger hairs rarely or never having the rodent base; or hairs more than 20 mm. long.....18

18 Larger guard hairs all white, medulla continuous, grayish, sometimes irregular in cross section (Fig. 33). Scales fairly conspicuous in xylene mount. There is a smaller set of intermediate hairs containing dark pigment granules. These hairs are often enlarged only in the distal portion and have cross sections flattened on one side as shown in Figure 34.

Opossum, *Didelphis v. virginianus*.

18′ Medulla of larger white guard hairs never irregular in cross-section; intermediate hairs otherwise. Or hair with more than two bands of color...19

19 Cross sections elliptical (Fig. 35); cortex always thick. As viewed longitudinally, the side of the medulla often is not parallel to that of the hair. Hairs never entirely white. Medulla of furhairs generally lacking or fragmental, rarely discontinuous. Cortex of furhairs with numerous pigment granules. An excellent point to be observed in some darkly pigmented hairs is a narrow zone of pale yellow at the periphery of the cross section.

Raccoon, *Procyon l. lotor*.

19′ Miscellaneous group.

MISCELLANEOUS GROUP

The miscellaneous group includes the following hairs:

1. Badger, *Taxidea t. taxus*, all hairs.
2. Skunk, *Mephitis nigra*, all hairs.
3. Fox, *Vulpes fulva*, and coyote, *Canis latrans*, the largest guard hairs.
4. Man and the domestic mammals.
5. Tail hairs of the squirrels, chipmunk, raccoon, and woodchuck.
6. Small head and leg hairs of all species.

It has not seemed possible to include these hairs in the key. Each mammal may have many different kinds of hairs, and there is too much similarity between various hairs of certain species. Further the hairs have neither scales, cross sections, or medullae distinct enough to permit positive identification. Figures 37 and 38 illustrate the reduced size of the medulla in many head and leg hairs. Inflated cross sections are typical of these small hairs as well as of the hairs of certain domestic mammals.

Usually a combination of several characteristics must be taken into consideration in order to identify the hairs of this group—when it is at all possible to do so. Many of these hairs can, however, be identified by comparison or through personal familiarity with them. Notes are given which may help identify a few of these hairs.

Hairs all white, all brown, or with two or three bands of brown and white. Large guard hairs stiff and bristle-like. Some of them when observed under the microscope are seen to have nodes and internodes in the basal portion. Medulla granular and continuous. Cross sections often irregular in shape (Fig. 36). Some smaller hairs have most of the cross sections elliptical and show a slit-like medulla. Furhairs with a fragmental, discontinuous, or continuous medulla which is usually less than $\frac{1}{3}$ as thick as the hair.

Badger, *Taxidea t. taxus*.

Hairs all white, all dark brown to black, or with a band of brown and white. Medulla is finely granular, but often concealed in the heavily pigmented hairs. Cross sections are circular to elliptical, or circular in the basal half and elliptical in the distal half. Fur hairs white or with brown pigment granules. Medulla of furhairs about $\frac{1}{3}$ as thick as the hair.

Skunk, *Mephitis nigra.*

LITERATURE CITED

(1) ALLEN, J. A.
1894. On the seasonal changes of color in the varying hare (*Lepus americanus* Erxl.). Bul. Amer. Mus. Nat. History. VI: 107–128.

(2) BOYD, EVLYN
1932. The pigmentary system and the dopa reaction. Proc. Roy. Soc. Edinburgh, 52: 218–235.

(3) DICE, L. R.
1927. A manual of the recent wild mammals of Michigan. Univ. Mich. Press, Ann Arbor, Michigan.

(4) GRANGE, WALLACE B.
1932. The pelages and color changes of the snowshoe hare, *Lepus americanus phaeotus*, Allen. Journ. Mamm. 13: 2, pp. 99–116.

(5) GUNN, CHARLES KENNETH
1932. Color and primeness in variable mammals. Amer. Nat. 66: 546–559.

(6) 1932. Phenomena of primeness. Canadian Journ. Research. 6: 4, pp. 387–397.

(7) HADWEN, SEYMOUR
1929. Color changes in *Lepus americanus* and other mammals. Canadian Journ. Research. 1: 189–200.

(8) 1934. Color changes in snowshoe hares. Canadian Journ. Research. 10: 5, pp. 539–556.

(9) HARDY, J. I.
1932. A method for studying the scale structure of medullated and pigmented animal fibers. Journ. Text. Inst. 23: T1–T5.

(10) HAUSMAN, LEON AUGUSTUS
1920. Structural characteristics of of the hair of mammals. Amer. Nat. 54: 496–523.

(11) 1924. Further studies of the relationships of the structural charteristics of mammalian hair. Amer. Nat. 58: 544–557.

(12) 1930. Recent studies of hair structure relationships. Sci. Mo. 30: 3, pp. 258–277.

(13) MANBY, J.
1932. An improved method for revealing the scale structure of wool and hair. Journ. Text. Inst. 23: T5–T13.

(14) 1932. II. Celluloid impressions of the surface structure of animal fibers. Journ. Roy. Micr. Soc. London. 53: 9–12.

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NOTES

The American Wildlife Institute has again invited the Wildlife Society to arrange the technical program for the Wildlife Conference, the next being the fourth, which will be held in Detroit, Michigan, February, 13 to 18, 1939.

Due to space limitations in the published proceedings, the program will be definitely restricted to not more than 60 papers, of 15 minutes each (5 minutes allowed for discussion). Papers must relate to wildlife management, and those will receive first consideration that present new facts and practical data heretofore unpublished. Since the time for each will be short, it is suggested that only summaries of lengthy papers be given, reserving details for publication in the printed Transactions of the Conference.

Preference will be given to reports on:

1. Studies of life histories, habits, distribution, and ecology, as bearing on management.
2. Relationships of wildlife to agriculture, forestry, and to streams, lakes, and marshes.
3. Improved techniques in making wildlife inventories, and food and cover surveys.
4. Environmental controls favoring wildlife, with specific reference to planting of food-producing trees, shrubs, and herbs, management of food patches and cover plantings, timber stand improvement, stream improvement, and other development practices.
5. Improved techniques in game and fur farming, fish rearing and planting, live trapping and transplanting.
6. Reactions of wildlife to livestock grazing, recreation and road development, timber management and utilization, flood control, soil conservation measures, drainage and pollution.
7. Practical applications of the results of food habits and disease investigations.
8. Studies on the economic, social, and esthetic values of wildlife.

Little consideration will be given to:

1. Statements of problems in wildlife management.
2. Plans for wildlife improvements, unless based on unpublished research findings.
3. Material published prior to the conference.
4. Regulatory laws and regulations.
5. Controversy representing chiefly personal opinion.
6. Papers requiring more than 15 minutes for delivery.
7. Papers to be given by proxy, unless for good reasons.

Papers should be well prepared, concise, and in *final form for publication at the time of delivery*. The Committee reserves the right to limit the number of papers on any one subject. The time required for showing motion pictures or slides will be considered a part of the 15 minute period. An abstract of the proposed paper must be submitted by January 15, 1939.

COMMITTEE ON ARRANGEMENTS

LEO K. COUCH, *Chairman*
JAMES O. STEVENSON
WILLIAM R. VANDERSAL
EDWARD L. WICKLIFF

Members of The Wildlife Society in Region V (Arizona, New Mexico, Texas, Oklahoma, and the Federated Mexican States) are notified that there will be a business meeting of the members of the region, in the Department of Biology, Baylor University, Waco, Texas, on November 11 at 5:00 P.M. Those attending the Texas Academy of Science meeting November 10–12 will have a chance to discuss matters of interest and, if advisable, formulate opinions for transmittal to the annual meeting of the Society in February. Also, election of the Regional Representative for Region V for the coming year will take place at the Waco gathering. Active members unable to attend should submit ballots, giving first and second choices, by mail to Dr. George E. Potter, Department of Biology, Baylor University, Waco, Texas, so as to arrive at that post office by November 10. Ballots sent by mail should be in sealed envelopes, marked "Ballot," so as to ensure that they will be opened *only* by the official tellers who will be George E. Potter and Homer E. Towns.

Elections of regional representatives of *all other* regions will be by mail ballot, as last year; there will be a nominating as well as an electing ballot. The three names receiving the highest number of votes will be submitted to the membership for final balloting. The nominating ballots will be mailed November first and must be returned to the Secretary by December 1, while the final ballots will be sent to the membership on December 10 and must be back by January 10, 1939. The Society is attempting to make the elections of regional representatives as fair as possible.

Authors of papers accepted for THE JOURNAL OF WILDLIFE MANAGEMENT please note carefully all attachments received with proof from the printer. There is a blue request for an *abstract* and a blue form on which it may be written or typed; this form when filled out is to be returned to the EDITOR. Please note the rubber-stamped notice in red that *both the original manuscript and the corrected proof* must be sent to the EDITOR. That request is repeated on a white sheet which also quotes prices for reprints and includes a form for ordering them. A yellow notice to authors of illustrated papers gives information as to how the engravings of plates and figures can be obtained. *All correspondence relative to reprints and cuts should be addressed to the* PRINTER.

The Committee on North American Fish Policy, E. L. Wickliff, Chairman, of the American Fisheries Society has issued a report in mimeographed form (10 pp., $8\frac{1}{2}\times14$ inches) that may be obtained from Mr. Wickliff, Ohio State Museum, Columbus. It points out the value of fishes, their regrettable depletion, and the opportunity of managing them as a crop. It discusses the functions in fish conservation of Federal and local governments; the objectives of fisheries administration, management, and research; pollution policy; discretionary powers; standardization of common names of fishes; and compilation of fisheries data. Of the 15 committee-men, 6 are members of The Wildlife Society.

A 7-page mimeographed leaflet entitled "Further Remarks on Writing

for the Biological Survey," by the Editor of THE JOURNAL OF WILDLIFE MANAGEMENT, issued in September 1938, may be had so long as the supply lasts upon application to Technical Adviser, Biological Survey, Washington, D. C. An earlier related leaflet "Preparing Scientific Manuscripts for the Biological Survey" also is available.

Biological Abstracts announces a plan under which subscriptions to subject groups of abstracts will be accepted. The group doubtless of most general interest to readers of THE JOURNAL OF WILDLIFE MANAGEMENT is I, Abstracts of General Biology, including General Biology, Biography-History, Bibliography, Evolution, Cytology, Genetics, Biometry, and Ecology. (Under the last-named head are grouped abstracts pertaining to Ecology of Wildlife Management, both aquatic and terrestrial.) The subscription price for this section is $4 per year. Four other abstract groups are available for subscription at rates varying from $5 to $9. One of these that will be of interest to many of our readers is group V, Abstracts of Animal Sciences to include Paleozoology, Parasitology, Protozoology, and Helminthology, Systematic Zoology, and Economic Entomology, the subscription for which is $6 per year.

Further details may be had and subscriptions may be placed by writing to Biological Abstracts, University of Pennsylvania, Philadelphia, Pa. The service rendered by Biological Abstracts is very helpful and important and it is fervently to be hoped that enough subscriptions will be received to enable the journal to continue on a self-supporting basis.

CORRESPONDENCE

LETTER TO THE EDITOR: "What is a wildlife specialist?"

For the past year or two we have been hearing and reading the term "wildlife specialist." Many of us are not certain as to its connotation. According to some standards, a wildlife specialist is one proficient in the "art" of slaughtering game. To some individuals he is the arm-chair biologist who delves into the philosophy of, and concocts theories concerning, wildlife. According to another standard, set up by one of our mid-western colleges, he is one who has completed an *eight-weeks training course offered by that institution!* Surely a wildlife specialist, in the true sense of the words, is more than any of the above standards imply. If he be not, I have been laboring under a gross misconception.

To invite discussion, clarification, and definition of the term, the standards (ideal of course) set up by the Department of Wild Game, Agricultural and Mechanical College of Texas, are here offered as something "to shoot at."

Gifford Pinchot's "What is a Forester" and Paul Errington's "Wildlife Research as a Profession" were very helpful in preparing the following set of criteria; Aldo Leopold's "What is a Game Manager" (MS) was read during the preparation of this paper. I have also had the advantage of working with Walter P. Taylor in determining our standards of achievement.

Our concept of a wildlife specialist:

1. He has a *keen* interest in and appreciation of wildlife, preferably from his boyhood days. The boy who comes to us knowing nothing of the birds, mammals, fishes, and plants of his home region likely will not succeed as a wildlife specialist. We would prefer to build on the foundation a boy has gained in FFA or 4-H Club wildlife work, Junior Audubon activities, hunting, fishing, trapping, or even egg collecting. Such boys have the interest at heart. We firmly believe that every Tom, Dick, and Harry is not properly qualified with the intelligence or interest to become a wildlife specialist. We can't afford to glut the field with misfits!

2. He is well grounded in the principles of Biology. He should know what the inside of a frog or a cat or a bird looks like. He should know plants, insects, and parasites, and he should have at least a nodding acquaintance with mathematics, chemistry, physics, geology, history, genetics, soils, and animal diseases. He should be familiar with the methods of farming practiced in his community.

3. He is able to prepare a paper that is good enough to be accepted by a professional journal in the field of his interest.

4. He is able to speak well enough to sell himself and his work to the reasonable part of the general public.

These are all general, but *basic*, requirements with which the Department of Wild Game has little or nothing to do except in the way of guiding and making recommendations to prospective graduates. In addition, he has acquired several skills in field, laboratory, and office techniques. This is the field in which our department functions.

1. He knows how to take proper field notes and is able to compile and interpret his findings.

2. He is thoroughly familiar with the wildlife in the area in which he is working.

3. He knows how to carry out a life history study of an animal; to interpret his findings and recognize their values.

4. He knows how to plan and carry out a census of an area.

5. He knows how to analyze and map an area showing kinds and location of various plants and other cover for wildlife; also the soil types when such information bears on the problem at hand.

6. He is able to take suitable photographs of wildlife subjects; he need not necessarily be a wild animal portrait photographer, however.

7. He knows how to make a collection of plants; to identify, properly label, and preserve them.

8. He has proficiency in collecting, preparing, and properly labeling study specimens of birds, mammals, reptiles, amphibians, and fishes.

9. He knows how to collect, preserve, and label stomachs, crops, pellets, and scats for food habits analysis; also, he is able to identify, roughly at least, the contents thereof.

10. He knows how to collect, preserve, and label animal parasites.

11. He knows how to camp, hunt, and fish: he gets along well with his fellow workers in the field and elsewhere, and is at home in the open.

12. He knows the literature in his particular field; how to digest and index it. In this connection, he joins the leading organizations and subscribes to the principal wildlife journals and has a working library of his own.

13. He knows something about the prominent men in his field, where they are, and what they are doing.

14. He has a good knowledge of the interrelations of living things among themselves and with their environment; he is able to diagnose habitats, tell what is the matter with them, and how to improve them.

15. He has a good understanding of land-use problems; the problems of forestry, grazing, agriculture, recreation, and soil and water conservation as related to wildlife problems.

If weighed on the scales of the above standards, a number of "wildlife specialists," including myself and several others of my acquaintance, will be found wanting. But there is no sin in "hitching our wagon to a star!" At least these standards, in my opinion, are far better than those mentioned in the first paragraph; certainly they are better than none at all.

Comments, criticisms, and discussion are in order.—

William B. Davis
Agricultural and Mechanical College of Texas
College Station, Texas

EMPLOYMENT SERVICE OF THE WILDLIFE SOCIETY

Purpose: This service will be operated as a department of the JOURNAL for the dual purpose of publishing information concerning (1), available positions and (2), qualifications of persons seeking such positions.

Limitations: To conserve the time of officers, the Employment Service will be confined to announcements of openings and statements of the qualifications of candidates. All correspondence will be between prospective employers and applicants, and not with officers of the Society. Appointments to nearly all federal and many state positions in wildlife management are based upon Civil Service ratings. Aspirants should therefore apply to the U. S. Civil Service Commission, Washington, D. C., or to corresponding state organizations for announcements of examinations. Appointing officers are invited to report vacancies and new positions to the Employment Service.

Procedure: Each member will be entitled to one five-line statement of his education, qualifications, and preferences as to type of position in each volume. Additional lines will be charged for at the rate of 5 cents per line, and additional insertions at the same rate for all lines required.

All communications for the Employment Service should be sent to the Editor, W. L. McAtee, Bureau of Biological Survey, U. S. Dept. of Agriculture, Washington, D. C.

HAHN, P. L., 228 Lenox Road, Brooklyn, N. Y. N. Y. State College of Forestry graduate 1925, 5 years wildlife and forestry work of which 2 were as Chief Forester and Wildlife Technician for the Farm Security Administration in Delaware. Civil Service ratings Wildlife Management 85%, Forestry 85%. Work desired: management or administration.

HYDE, A. SIDNEY, 3997 Washington St., San Francisco, Calif. B.A., M.A. University of Ill.; Ph.D. University of Mich. Six years teaching zoology; junior biologist in Food Habits Research, Biological Survey, under W. L. McAtee; field naturalist Roosevelt Wild Life Station; now in charge of Wildlife Project (ERA), National Park Service, under E. Lowell Sumner, Jr. Desire more permanent position in teaching, research, or management.

THE CONSTITUTION AND BY-LAWS OF THE WILDLIFE SOCIETY

CONSTITUTION

Article I—Name.

The name of this Society shall be The Wildlife Society.

Article II—Objectives.

The principal objectives of the Society shall be: (1) Establishment of professional solidarity and the maintenance of the highest possible professional standards; (2) development of all types of wildlife management along sound biological lines; (3) publications to effect these ends; and (4) protection of the interests of its members.

Article III—Membership.

Sec. 1. The membership of this Society shall consist of Active Members, Associate Members, and Honorary Members.

Sec. 2. Active Members shall be persons professionally engaged in the practice or teaching of wildlife management, in wildlife administration, in wildlife research, or in graduate study of these subjects, who are graduates of a school approved by the Council, or who, in the opinion of the Council, have acquired an understanding of wildlife management principles and techniques comparable with that required by a school approved by the Council.

Sec. 3. Qualifications of applicants for Active Membership shall be passed upon by a standing committee of five members who shall be nominated by the Council and elected by the Society at its annual meeting; three members of the committee to be elected in odd numbered years, two members in even numbered years, to hold office for two years each. Election of applicants for Active Membership shall be made by the Council from among those recommended by the Membership Committee.

Sec. 4. Any person may become an Associate Member upon recommendation of two Active Members and acceptance by the Secretary.

Sec. 5. Honorary Members shall be persons who, upon the unanimous recommendation of the Council and a two-thirds vote at any stated meeting of the Society, are thus recognized for their distinguished service or outstanding achievement in the field of Wildlife Management.

Sec. 6. Only Active Members shall be entitled to vote, to hold office, and to represent the Society officially. All classes of members shall receive the journal and such other publications of the Society as the Council may direct.

Article IV—Officers.

Sec. 1. The officers of the Society shall be a President, a Vice-President, a Secretary, and a Treasurer.

Sec. 2. The officers shall be elected annually from among the Active Members, shall be eligible for re-election, except that the President and Vice-President shall not succeed themselves, and shall perform their duties until their successors qualify. Officers shall be elected by a majority vote at the annual meeting and their official terms shall commence at the close of the meeting at which they are elected.

Sec. 3. The President shall preside at meetings of the Society, shall be Chairman of the Council, shall appoint all Committees, except the Membership Committee, including those established by the Council, and perform other duties incident to his office.

Sec. 4. In the absence of the President or in his inability to act, his duties shall be assumed by the Vice-President. In the event neither one can serve, the Council shall appoint a President pro tempore.

Sec. 5. The Secretary shall be the Executive Officer of the Society under the general direction of the Council. He shall issue notices of annual or special meetings of the Society. A report covering his activities during the preceding year shall be made by him to the Society at its annual meeting.

Sec. 6. The Treasurer shall be responsible for all funds of the Society except permanent funds held in trust and shall be bonded in suitable amounts as decided by the Council and at the Society's expense. His accounts shall be audited at the close of each year as directed by the President before presentation at the annual meeting of the Society.

Sec. 7. Vacancies among the officers shall be filled by vote of the Council from among the Active Members for the unexpired term of the office.

ARTICLE V—Council.

Sec. 1. The Society shall be governed by a Council composed of the President, Vice-President, Secretary, Treasurer, and at least one representative from each of the Regions as defined in the By-laws. The Regional Representatives shall be elected annually, shall be eligible for re-election and shall take office at the close of the annual meeting following their election.

Sec. 2. The Council shall appoint the Editor; shall have power to fill vacancies occurring in its numbers; shall recommend to the Society for action By-laws not inconsistent with this Constitution and shall perform such other duties as are herein prescribed. Not less than one-half of the Members of the Council shall constitute a quorum.

ARTICLE VI—Meetings.

Sec. 1. The Society shall hold an annual meeting and such other meetings as the Council may direct at places and dates selected by them. Due notice of such meetings shall be given by the Secretary at least thirty days in advance.

Sec. 2. Resolutions passed at a meeting of the Society by less than a majority of its Active Members shall represent the majority opinion of the meeting, but shall not be binding on the Society unless subsequently approved by the Council.

ARTICLE VII—Sections.

Sections of the Society may be authorized by the Council upon petition of ten or more Active Members. Sections may adopt necessary By-laws, providing that no part of them shall conflict with the Constitution of this Society. A report of its activities shall be presented by each section at the annual meeting of the Society.

ARTICLE VIII—Dues and Funds.

Sec. 1. The annual dues of Active Members shall be $5.00 and of Associate Members, $3.00. No dues shall be charged Honorary Members.

Sec. 2. Annual dues shall be payable from January 1, in advance. Members in arrears shall forfeit their rights and privileges and shall receive no publications until such dues are paid.

Sec. 3. All monies accruing to the Society received for undesignated purposes shall constitute the Permanent Trust Fund, the proceeds from which shall be utilized to carry forward the work of the Society as directed by a three-fourths vote of the Council. In the absence of such direction, this income shall be reinvested by the Trustees.

Sec. 4. Bequests, grants, or trusts made for the purpose of advancing the field of Wildlife Management and/or The Wildlife Society, may be accepted by the Society, providing the Council shall have first favorably considered the objects and specifications set up by the trust. These shall be placed in the Permanent Fund.

Sec. 5. The Permanent Trust Fund of the Society shall be controlled in trust by a board of three Trustees with power to sell and reinvest according to their judgment. One Trustee shall be elected at each annual stated meeting for a term of three years. In case of vacancies caused by suspension, resignation, or death, successors may be appointed by the Council for the remainder of the term. The Trustees shall be bonded in suitable amounts as directed by the Council and at the Society's expense.

ARTICLE IX—Amendments.

The Constitution may be amended by a two-thirds vote of the Active Members of the Society, replying by ballot to a notice of the proposed amendment. Such notice must be submitted to all voting Members at least thirty days previous to the closing date for the receipt of ballots. Amendments may be referred to the Society for action either by a two-thirds vote of the voting Members at any stated annual meeting, or by a favorable vote of at least two-thirds of the Council.

BY-LAWS

I. Election of Officers.

The President shall appoint a nominating committee, which shall recommend to the Society candidates for each office. Members shall have the privilege of nominating additional candidates from the floor before the ballot for each office. In case a ballot does not result in a majority for any candidate, subsequent ballots shall be limited to those two candidates receiving the largest number of votes on the previous ballot. Ten per cent of the Active Members of the Society shall constitute a quorum.

II. Election of Council.

Representatives to the Council shall be chosen, one from each of the following Regions:

Region 1:

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Maryland, Delaware, District of Columbia, West Virginia, and eastern Canada west to and including Toronto.

Region 2:

Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, and West Indies.

Region 3:

Ohio, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Illinois, Indiana, and Ontario west of Toronto.

Region 4:

North Dakota, South Dakota, Montana, Wyoming, Nebraska, Colorado, Kansas, and Manitoba, Alberta, and Saskatchewan.

Region 5:

Arizona, New Mexico, Texas, Oklahoma, and Mexico.

Region 6:

Washington, Oregon, California, Idaho, Nevada, Utah, and British Columbia, Alaska, and Hawaii.

Additional Regions may be established for similar representation upon approval by the Council. Representatives of the Council shall be elected in each Region by any plan acceptable to the Council.

III. Order of Business.

The order of business at the annual stated meeting, unless changed by a two-thirds vote of the Active Members present, shall be as follows:

1. Reading and approval of the minutes of the previous meeting.
2. Report of the Secretary.
3. Report of the Treasurer.
4. Report of Regional Representatives and Sections.
5. Appointment of temporary committees.
6. Report and recommendations by the Council.
7. Action on business reported by the Council.
8. Reports of committees.
9. New and unfinished business.
10. Election of officers.

IV. Delinquents.

The names of members whose dues are in arrears for two years shall be presented to the Council for action.

V. Fiscal Year.

The fiscal year of the Society shall end December 31.

VI. Editor.

The Editor shall be appointed by the Council. He shall serve for one year, or until his successor is appointed, and shall be responsible for all matters relating to the publications of the Society, subject to such restrictions as may be imposed by the Council.

VII. By-laws.

By-laws may be adopted, amended, or repealed at any annual meeting by a majority vote of the Active Members present.